RECOVERING CAPITAL EXPENDITURES: THE RAILROAD INDUSTRY PARADOX

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Following deregulation in 1980, the U.S. freight railroad industry invested large amounts of capital, expanded output and increased earnings, but — paradoxically — it did not earn a competitive return on investment. As a result, investors became increasingly wary of expanding investment in this industry, even as demand for rail transportation services continued to grow. In recent years, investment has been constrained, capacity has become more restricted, prices have risen, and returns to investment have improved but continue to fall below the industry's cost of capital.

This research examines the possibility that railroad capital expenditures represent an incremental cost of traffic that was, and may continue to be, substantially underestimated in industry calculations of marginal cost. As a result, railroad pricing strategies may rely on overstated contribution ratios that do not consider the full incremental capital cost associated with each shipment. Because railroads invest more capital, as a percentage of revenue, than any other major industry sector, they are particularly vulnerable to such miscalculations. All variable costs (expenses and investments) must be included in marginal cost calculations if the economic value of the firm is to be maximized in the way it prices its goods and services.

This research combines engineering, economic, and financial methods and makes contributions in each area. Railroad maintenance strategies that rely more heavily on capital investment are more cost effective. Infrastructure capital spending is caused by current and future output, and is therefore a short run marginal cost. Railroad marginal cost formulae appear to substantially underestimate the true incremental nature of ongoing capital expenditures. Regulatory average variable cost formulae do not incorporate variable capital expenditures suggesting that Surface Transportation Board estimates of revenue to variable cost are overstated, subjecting a larger share of rail traffic to potential economic regulation than would otherwise occur.

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BY

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DISSERTATION

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Dedications

This dissertation is dedicated to my father, Dr. George Murray Grimes. Raised as a depression era farm child in west Tennessee, he overcame many obstacles to study veterinary medicine at Texas A&M University. He became a leader in veterinary education in the U.S. Army, conducted advanced studies at Texas A&M and Tulane Universities, served as a professor at the University of Illinois, and was a worldwide missionary dedicated to improving the health of impoverished peoples. My father has served as an inspiration on many levels, both personal and spiritual. When I was a child, he showed me the world, from east to west. When I was a teenager, he was patient and encouraging. He always demonstrated integrity in difficult decisions and perseverance in difficult challenges. He demonstrated to me that love, family, spiritual matters and knowledge were more important than personal possessions or wealth. He continues to be my great inspiration and educator.

This dissertation is also dedicated to the memory of Professor W. W. Hay, who provided guidance and inspiration during my undergraduate years, and kept railroad engineering education alive and thriving almost single handedly. My last meeting with "Doc Hay" was in late 1997 shortly before his death. Despite difficulties caused by his stroke, we talked about the students that he had taught and his significant contributions to this industry. He would be greatly pleased that his legacy has been carried forward at the University of Illinois by a new group of dedicated educators, researchers, and students.

Acknowledgements

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Finally, and fundamentally, I could not have started much less completed this effort without the support of my entire family, George, Lillian, Bill, Elizabeth, and Chris. My father for his attentive ear, lifelong encouragement, and patience and faith. My mother for her constant love and instilling a sense of confidence. And my son, Chris, for encouragement and providing that last push, advising, *"Ya gotta go for it, Dad."*

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1.0 Introduction

"Estimates of the cost of handling added traffic are as old as the railroads themselves."
Interstate Commerce Commission, *Rail freight service costs*, 1943

"Some carriers are considering … the elimination of … whole lines of business."
American Association of State Highway and Transportation Officials, 2002

"Being a 'growth' railroad is simply not a terribly sound business or investment strategy."
CitiGroup, 2003

1.1 Principal Hypothesis

The principal hypothesis of this dissertation is that railroad capital expenditures represent an incremental cost of traffic but are largely excluded from marginal cost estimates. This results in sub-optimal pricing decisions and sub-optimal returns to invested capital. Because railroads invest more capital, as a percentage of revenue, than any other major industry sector, they are particularly vulnerable to such mis-calculations.

I propose that infrastructure capital expenditures are, on the whole, correlated with and caused by current and future output and should be included in marginal cost estimates. I also propose that U.S. freight railroads and their economic regulators do not properly interpret these incremental investments as marginal cost. If so, then (1) railroad pricing and investment strategies do not optimize return on invested capital, and (2) Surface Transportation Board estimates of revenue to variable cost (R/VC) are overstated, subjecting a larger share of rail traffic to potential economic regulation than would otherwise occur.

The concept that ongoing expenditures for investment should be considered in the estimation of marginal cost, and therefore included in criteria for pricing decisions, was not found in the financial literature but does have foundation in economic theory. It appears to represent a gap in the application of economic theory to railroad cost accounting methods.

Railroads have not mis-applied current financial theory but they may be struggling to resolve the paradox of maximizing earnings (net income) or returns to invested capital (free cash flow). The solution to this paradox, according to this thesis, requires an extension of how cost accounting models incorporate economic theory. A robust integration of these concepts highlights the need to treat incremental investment as an incremental cost. Firms with large variable investment requirements can use pricing strategies to either maximize earnings (net income) or returns to invested capital (free cash flow), but not both at any given moment. Variable investment must be included in marginal cost calculations if the economic value of a firm is to be maximized in the way it prices its goods and services.

1.2 Key Findings

The key findings of this dissertation are:

1) The intrinsic cost of maintaining railroad infrastructure does not substantially vary among Class I railroads, and apparent differences in unit maintenance cost can be explained by the degree to which individual firms apply renewal strategies,

2) Railroad maintenance strategies that employ a greater portion of renewal-based maintenance are more cost effective than those that use less renewal,

3) Railroad infrastructure investment (capital expenditures) is principally a function of current and future demand,

4) Regulatory cost formulae underestimate actual cost variability by not including variable capital expenditures, subjecting a larger share of rail traffic to potential economic regulation than would otherwise occur,

5) Commercial pricing formulae used by railroads appear to underestimate the true incremental nature of capital expenditures resulting in sub-optimal pricing decisions and returns to invested capital,

6) Significant differences exist between accepted railroad cost accounting practice and economic theory regarding marginal cost analysis, and

7) This analysis suggests that firms with substantial variable investment cannot maximize both net income and free cash flow, at least in the short run.

1.3 Significance of and Reasons for Research

Following deregulation in 1980 through the late 1990's, U.S. freight railroads increased capital spending, expanded output, reduced costs, and improved service. During the same period, they consistently failed to earn a rate of return commensurate with their cost of capital (U.S. Congress House Committee 1998, 2001; Flower 2003a; Flower 2003b; Gallagher 2004, Hatch 2004). Since 1998, railroads have become more conservative with capital spending as investors have become increasingly skeptical about the industry's financial competitiveness (Flower 2003a; Flower 2003b; Gallagher 2004; Hatch 2004). Shippers and public transportation officials are increasingly concerned about the effects of further constraints on rail investment (U.S. Congress House Committee 2001; AASHTO 2002; Hatch 2004; Hensel 2004). Transportation officials predict there will be additional costs to transportation users of $400 to $900 billion if future rail investment is constrained (AASHTO 2002). This research offers one explanation as to why railroads earn poor returns on investment despite seemingly healthy rates of earnings growth. If corrected, railroads may find it easier to earn their cost of capital, resulting in fewer external constraints on capital investment.

Transportation industry professionals have often expressed concern over the railroad industry's inability to earn a competitive return on investment, or its cost of capital (U.S. Congress Senate Committee 1987; U.S. Congress House Committee 1998, 2001; AASHTO 2002; Hatch 2004). The specific direction of this research was established when I first discovered a correlation between capital expenditures and output while studying economic and financial theory. An experiential knowledge of industry and regulatory cost procedures lead me to suspect that there might be a systemic error in the way capital expenditures were reflected in marginal cost estimates and pricing strategy.

This research presents a new explanation for a chronic problem of significance to the railroad industry, and it presents new financial techniques that may be useful to other industries with substantial variable investment requirements.

1.4 Dissertation Organization

This dissertation is designed as a series of chapters, three of which are intended as individually publishable papers. As a result, each chapter will cover some material discussed in previous chapters. Chapters 2-4 form the core of the dissertation. Chapter 5 presents a summary of findings and additional conclusions. Chapter 6 identifies additional research needs. Chapter 7 is a compendium of related literature dating from the 1840's to 2004. References cited and curriculum vita follow chapter 7.

Chapter 1: Introduction

This chapter presents the principal hypothesis, key findings, significance of the research, a description of each chapter, and contributions claimed.

Chapter 2: Cost Effectiveness of Railway Infrastructure Renewal Maintenance

This chapter discusses how and why railroads make capital investments in infrastructure from an engineering perspective. Railroads maintain their infrastructure through a mix of ordinary maintenance activities and periodic renewal programs. Different railways use different proportions of these two approaches and the cost effectiveness of emphasizing one maintenance regime over the other has not been previously analyzed empirically. The objective is to investigate the cost-effectiveness of renewal-based maintenance strategies using data from industry sources. The primary hypothesis is that an emphasis on infrastructure capital expenditures reduces total infrastructure maintenance cost. Alternative hypotheses are tested with regard to the effects of railroad size and density.

The results indicate that engineering management strategies that place more weight on renewal maintenance relative to ordinary maintenance reduce total maintenance cost. Railroad size and average density are significant but secondary factors. The effects of size and density appear consistent with recent econometric studies on the nature and behavior of railroad costs.

Chapter 3: Railway Output and Infrastructure Investment

This chapter investigates the relationship between infrastructure capital expenditures and railroad output. The hypothesis tested is that infrastructure capital expenditures are variable with, and caused by, changes in railroad output. Alternative hypotheses tested are that free cash flow and/or net income are primary causal drivers of infrastructure capital expenditures.

My analysis suggests that, over the past 15 years, changes in annual investment were closely correlated with, and caused by, changes in annual output. Lag analysis suggests that annual infrastructure investment is principally forward looking, determined by current and future output, and not by past output. As a result, I conclude that capital expenditures are marginal costs, and that regulatory variable cost formulae are incorrect because they do not treat them as such. Annual investment appears to be a better predictor of free cash flow and net income than output.

Chapter 4: Recovering Capital Expenditures in Prices

This chapter presents a new method to calculate the percentage of capital expenditures that are reflected in railroad price floors. This methodology integrates economic and accounting concepts of cost, and compares trends in net income and cash flow to estimate the price component for recovery of variable investment and variable capital expenditures. The primary hypothesis is that, contrary to rational economic behavior, the proportion of variable capital expenditures included in railroad prices is substantially less than one. A sensitivity analysis is conducted to determine the degree to which other factors may influence the results of the analysis.

My analysis suggests that railroads systematically underestimate the true incremental nature of capital expenditures in their estimates of marginal cost, contribution ratios, and price floors.

Chapter 5: Summary and Discussion

This chapter provides a summary of Chapters 2-4. It presents an explanation, from a historical viewpoint, for the mis-application of marginal analysis with respect to railroad capital expenditures. Engineering practices are examined to highlight the variable nature of capital expenditures. Public policy questions are analyzed, and implications of this research for firms with substantial variable investment are discussed.

Chapter 6: Future Research

This chapter presents additional research needs based on the broader interpretation of these findings. Research is needed to develop a method to properly allocate capital expenditures to specific traffic movements using transportation network theory and economic benefit analysis. The degree to which other industries may under-allocate variable investment in marginal cost estimates should be investigated. Research is recommended to test the relationship between firm value and investment strategy based on new derivations of firm value and free cash flow with respect to variable investment.

Chapter 7: Literature Survey

The literature survey is a compendium of literature that was used, directly or indirectly, in the development of the dissertation, and includes a combination of relevant economic, regulatory, financial, and engineering topics. Part of this material is presented in Chapters 2 through 5. The survey presents a broader and more complete picture than provided in the previous chapters. The material is presented in chronological order so the reader can more fully comprehend how railroad economic theory developed over 165 years to its present state.

1.5 Multi-Disciplinary Approach

The chapters that form the core of this research program tend to blend different disciplines, but each has a different focus. Chapter 2 focuses on railroad engineering issues related to optimal maintenance strategies. Chapter 3 combines engineering practice and economic theory to define the relationship between infrastructure investment and output. Chapter 4 combines economic and financial theory to analyze commercial costing practices. Chapter 5 presents a history of economic theory and cost accounting methods to explain current mis-interpretations, and demonstrates how to correct these errors using current engineering practices. The chapters are designed to build upon each other through a series of inquiries (primary discipline(s) in parentheses):

- Why do railroads make capital investments in infrastructure? (engineering)
- What are the most efficient strategies used to maintain infrastructure? (engineering)
- What are the relevant economic attributes of capital investment? (economics)
- Can financial trends provide insight into the commercial interpretation of the economic attributes of capital investment? (economics and finance)
- How do these economic attributes compare with current regulatory and commercial interpretations? (economics and finance)
- Why would economic theory be mis-interpreted by industry and regulatory institutions? (economics, engineering, and finance)
- What guidance can be used in future situations? (engineering and economics)

Specific contributions are claimed for each discipline, as follows:

Contributions to Civil (Railroad) Engineering

- A new technique that segregates railroad capital expenditures into renewal maintenance and capacity expansion categories,
- A new model that estimates the effectiveness of renewal strategies in the maintenance of rail infrastructure, and
- A finding that baseline maintenance costs do not vary from one railroad to the next if renewal maintenance strategies are taken into account.

Contributions to Economics

- A new, post-facto, pricing analysis tool,
- A new method that estimates cost-related price components.

Contributions to Finance

- A new model of free cash flow using quasi-economic variables,
- A new method to estimate the degree to which investment cash flows are reflected in price floors, and
- A new method to relate changes in firm value to changes in free cash flow with respect to variable investment.

2.0 Cost-Effectiveness of Railway Infrastructure Renewal Maintenance

"In his advice, the engineer rarely is able to confine himself to technological considerations alone. The decision to install a new piece of equipment or to undertake a new process must take into account demands and money costs. … But once all of the elements are incorporated into his analysis the engineer … should not be surprised to find that he has all along been talking economics."

W. J. Baumol and S. M. Goldfield, *Precursors in Mathematical Economics*, 1968

Since the railway infrastructure investment boom of the mid-1980's, all Class I railroads, have made significant efficiency gains in infrastructure maintenance that are the result of improvements in a number of areas. Technological advancements in infrastructure components such as cleaner and harder steel have reduced asset life cycle costs. Improved component management has also reduced costs, for example new developments in rail grinding and lubrication (IHHA 2001). Infrastructure maintenance delivery systems and maintenance equipment technology has changed considerably. Better performance measurement tools and cross-functional teamwork has transformed additional engineering practices. (A Class I railroad is a U.S railroad that meets a revenue threshold of $277.7 million.)

Railroads maintain their infrastructure using a combination of ordinary maintenance and renewal maintenance techniques. Ordinary maintenance generally includes the replacement of small quantities of infrastructure components using relatively small gangs and small equipment, whereas renewal maintenance techniques involve the replacement of larger quantities of components with larger gangs and bigger, more sophisticated and more expensive equipment. Ordinary maintenance activities are normally charged to operating expense and renewal maintenance programs to capital expenditures according to Surface Transportation Board (STB) accounting requirements (U.S. Senate Committee 1995).

Over the past 20 years, according to this research, all Class I railroads have increased their use of renewal-based maintenance compared to ordinary maintenance, however, the degree to which they do so varies substantially (Figure 2.1). Some railroads allocate less than 40% of their total maintenance budget to renewal programs, while others consistently allocate over 60%. There is also substantial variation in renewal regimes among international railroads (Burns 1983).

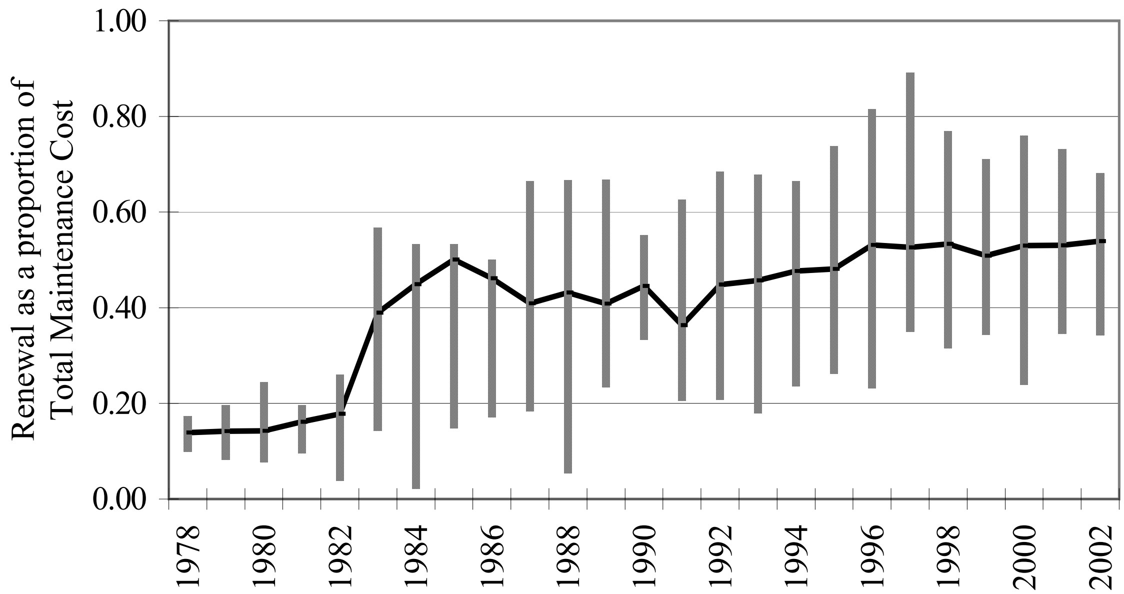

Figure 2.1: Renewal as a proportion of total maintenance cost (line indicates weighted average and bars indicate range among individual Class I railroads) as derived in this research.

Both renewal capital expenditures and ordinary maintenance expenses represent costs incurred for maintenance of infrastructure, but the engineering management strategy of each approach has a subtle yet significant difference. Renewal based maintenance results in better average track condition over the life cycle of the track but also greater variability. Selective ordinary maintenance, on the other hand, is generally used to maintain track to a consistent minimum standard (Figure 2.2) (Burns 1980). Both are required, but an emphasis on one or the other can result in a wide variation of

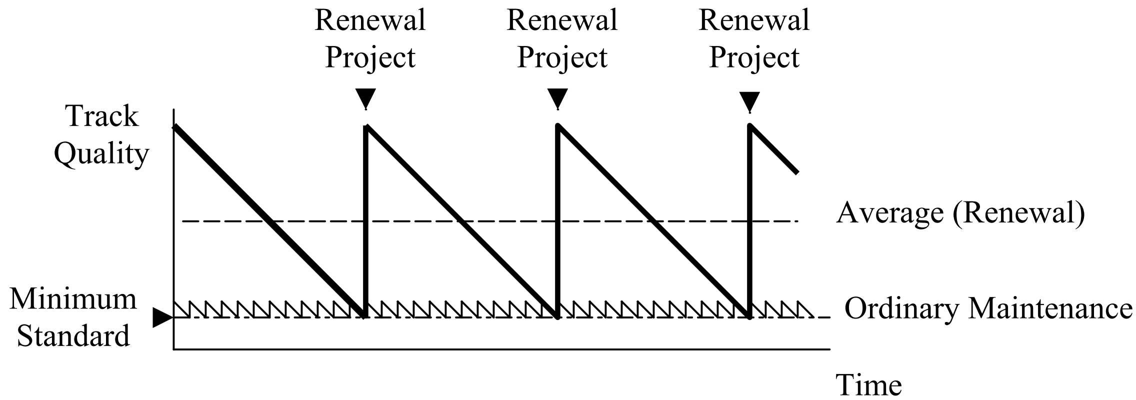

Figure 2.2: Comparison of the temporal relationship between renewal and ordinary maintenance, and track quality

maintenance costs. A low-quality track might support relatively high-axle loads with a high maintenance regime; conversely higher investment can mean higher axle loads and relatively low maintenance (Australian Government Bureau of Transport and Regional Economics 2003). There are also substantial differences in the equipment employed and the schedule of work.

In general, renewals involve capital expenditures made to replace and/or improve infrastructure components in response to, or anticipation of, wear and tear caused by output (defined here as gross ton miles). In contrast, capital expenditures for expansion of facilities (terminals and yards, siding or mainline trackage, signal or dispatching systems, etc.) are made to accommodate rail traffic growth and are called additions. However, post facto railroad financial statements do not segregate capital expenditures into these categories. For the purposes of this study, I classify Ordinary Maintenance as maintenance that is expensed, Renewal Maintenance as maintenance activity that is capitalized, and Additions as capacity expansion (Table 2.1).

The question addressed in this chapter is whether there is a relationship between the engineering management strategy, in terms of its relative emphasis on renewal or ordinary maintenance, and the overall cost effectiveness of the maintenance function.

Table 2.1: Infrastructure Costs: Purpose, Study Classification and Accounting Category

<table>
<tr><th>Purpose</th><th>Study Classification</th><th>Accounting Category</th></tr>
<tr><td rowspan="2">Infrastructure Maintenance</td><td>Ordinary Maintenance</td><td>Operating Expense (excluding depreciation)</td></tr>
<tr><td>Renewal Maintenance</td><td rowspan="2">Capital Expenditures</td></tr>
<tr><td>Capacity Expansion</td><td>Additions</td></tr>
</table>

2.1 Background

Track maintenance by renewal is not new. It was originally developed in the U.S. in the early 1900's and even then it was believed to be less expensive (Burns 1981). Renewal was originally performed by hand or with relatively simple machines. Recent changes in technology and practice have led to improvements in overall efficiency for both ordinary and renewal-based maintenance techniques. However, the efficiency difference between small section gangs performing selective maintenance (characteristic of ordinary maintenance) and large mechanized gangs (characteristic of renewal maintenance) has increased. This difference results, in part, from improvements in delivery technology including track renewal systems, tie-handling equipment, surface and lining equipment, rail laying equipment, and ballast delivery systems. Newer maintenance of way equipment is safer, cleaner, easier to maintain, and easier to operate than earlier models (Judge 1999). Advances in computerization have improved the reliability of this equipment (Brennan 1997). Although improvements have been made in all types of machinery, the high-end, high-production equipment has provided much of the recent productivity improvement (Kramer 1997). These advances and the larger scale of equipment and gangs permit greater economies of scale compared to ordinary maintenance.

Renewal programs also tend to have relatively long planning horizons so that track possessions can be coordinated with transportation operations to minimize service disruptions. These programs may target various track components for replacement and the scope of individual programs may vary widely. For example, a tie program may target replacement of crossties without renewing the ballast section of the track structure, while a track surface and lining program may renew both crossties and ballast. Maintenance "blitzes" are an ultimate kind of renewal program involving most or all track components. The maintenance blitz is used to renew infrastructure in a manner intended to minimize track downtime (Stagl 2001). Engineering departments co-ordinate the large renewal projects with transportation and marketing departments (Foran 1997). Maintenance planning has improved through advancements in information technology (Brennan 1997) and railroads have transformed material handling systems as well as on-site production (Kramer 1997).

Renewal activities normally require significant track possession windows that can be difficult to obtain at high train densities. Spot or selective maintenance activities normally require shorter track possession times and thus are less difficult to obtain even at higher train densities. Consequently, high train densities can lead to a reduced reliance on renewal work (Kovalev 1988). Additionally, renewal maintenance often involves high-cost high-maintenance equipment that necessitates high utilization rates that are difficult to justify for small maintenance regimes. For this and other reasons, routine ordinary maintenance continues to be an important activity in conjunction with renewal regimes to minimize total maintenance costs (Grassie 2000).

Studies on railway maintenance costs do not provide information on the relative efficiency of emphasizing renewal-based maintenance in the U.S. Over the period 1994 to 2000, maintenance costs in Europe decreased while expenditures for renewals increased, and enhanced renewal activity generally resulted in lower maintenance costs (International Union of Railways 2002). Another study found that maintenance and renewal practices on the Netherlands railway system had a direct influence on the financial and operational performance and that the appropriate combination was critical to overall operational performance (Swier 2004). However, neither of these European studies provided data to support or quantify their conclusions.

These developments lead to the question, does reliance on renewal-based maintenance strategy reduce total maintenance cost? Presumably the trend toward renewal-based maintenance reflects a belief that it is more efficient or effective in some manner. However, quantitative analyses of data evaluating this question have not previously been published. In this chapter I develop an analytical method to evaluate this issue using a cross sectional analysis of Class I railroad financial and operating data reported to the Association of American Railroads (AAR 1978-2002a) under rules promulgated by the STB (U.S. Senate Committee 1995).

2.2 Methodology

The overall process is illustrated in Figure 2.3.

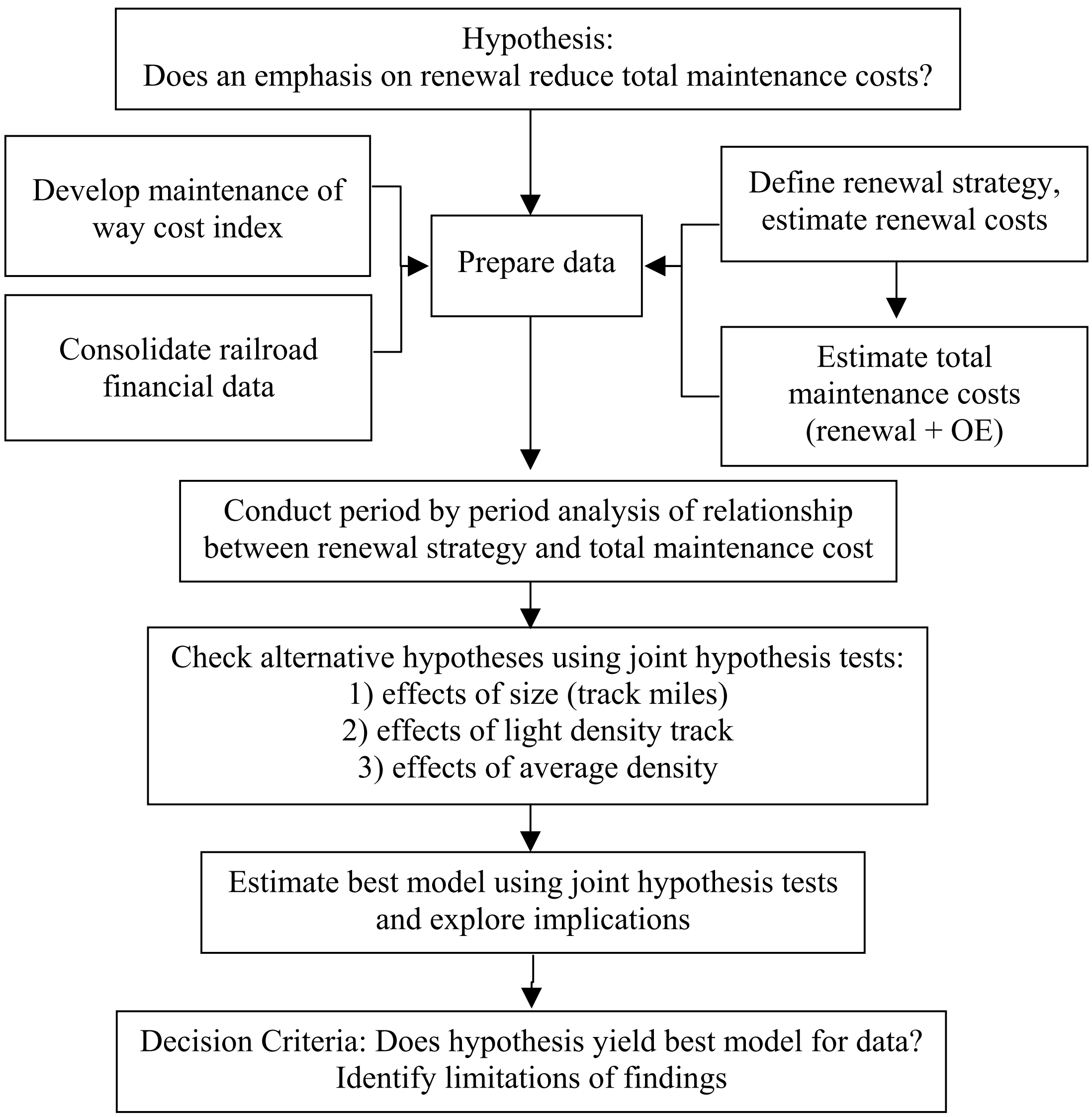

Figure 2.3: Methodology and decision analysis

Financial and operating data for individual Class I railroads were modified to permit study of the maintenance components of these data. A railroad infrastructure cost index was developed from components of the AAR railroad cost index. Because railroad financial statements do not segregate capital expenditures into renewals and additions, a method was developed to estimate renewal capital expenditures so that total maintenance costs, both renewal (capital expense) and ordinary maintenance (operating expense), could be combined to evaluate total maintenance costs. Because of consolidations in the industry during the study period, railroad financial and operating data were consolidated to reflect the 2001 industry structure. A series of standard linear regression analyses and F-tests were conducted to compare several alternate models regarding the effect on unit maintenance cost, including the effect of renewal strategy, railroad size, the percentage of light density track miles, and average track density. If renewal strategy is a significant and influential variable in the best model, the hypothesis can be accepted.

2.3 Data Preparation

2.3.1 Infrastructure Cost Index

An infrastructure cost index (MOW RCR) was developed from components of the AAR Railroad Cost Recovery Index (AAR RCR) (Table 2.2). The AAR RCR is based on data provided by all Class I railroads (AAR 1980-2002b). It is comprised of 10 components, which are then combined into four groups, 1) labor, 2) fuel, 3) material & supplies, and 4) all other. Calculation of the infrastructure cost index considered these cost groups as follows:

1) The labor cost index (Labor) reflects changes in the average unit price of wages and fringe benefits. The average wage for maintenance of way employees compared to all railroad employees has remained fairly constant over the period of the study, and the overall labor index was therefore appropriate for an infrastructure cost index.

Table 2.2: AAR Railroad Cost Index Components Indexed to 1981, Railroad Composite Cost Indexed to 1981 (AAR RCR), and Infrastructure Composite Cost Indexed to 1981 and 2001 (MOW RCR)

Year	Labor Index	Fuel Index	M&S Index	Other Index	AAR RCR	MOW RCR	MOW RCR
1978	74	37	73	74	69	73	36
1979	81	56	80	81	77	81	40
1980	89	83	92	90	89	90	45
1981	100	100	100	100	100	100	49
1982	112	95	101	106	107	108	53
1983	123	83	96	110	111	116	57
1984	130	82	96	114	115	121	60
1985	132	77	100	116	117	123	60
1986	138	49	98	119	118	127	62
1987	144	53	92	121	121	130	64
1988	153	48	96	129	128	137	67
1989	158	56	101	135	133	142	70
1990	163	69	105	143	140	148	73
1991	172	67	115	148	146	155	76
1992	180	64	124	149	150	162	80
1993	180	64	128	151	151	163	81
1994	183	60	132	155	153	166	82
1995	192	60	133	164	167	174	86
1996	197	71	133	170	167	179	88
1997	201	69	136	173	169	184	91
1998	206	55	137	180	172	189	93
1999	204	56	137	180	171	188	93
2000	216	90	136	187	187	195	96
2001	228	88	140	191	192	203	100
2002	238	76	140	193	194	208	103

2) The fuel cost index (Fuel) was not included in the MOW RCR because maintenance of way fuel expense is not separately identified in financial reports and, as a result, the proportion of fuel cost to overall cost could not be calculated. Additionally, maintenance of way equipment is often fueled directly from locomotive diesel storage tanks that are not charged to maintenance. Fuel expenses represent a relatively small percentage of total maintenance of way expenditures and should not affect the overall results.
3) The material & supplies cost index (M&S) measures cost changes in a group of items that represent the preponderance of purchases by the largest railroads. This index component was included in the MOW RCR because M&S costs are a significant portion of total maintenance of way costs.

4) The other cost index (Other) includes equipment rents, depreciation, purchased services, taxes other than income and payroll, and other expenses. This index component was included in the MOW RCR because these costs are a substantial portion of total maintenance costs.

The overall annual infrastructure cost index was then developed by multiplying each index (Labor, M&S, and Other) times the relative proportion of each component of total maintenance of way expense for each year. This calculation is shown below.

$$\text{MOW RCR} = [\{R_L (M_L/M_T)\} + \{R_M (M_M/M_T)\} + \{R_O (M_O/M_T\}]$$

where:

R_L = AAR Labor Index

M_L = Class I RR MOW Labor Expense

M_T = Class I RR Total Maintenance of Way Expense

R_M = AAR Material and Supply Cost Index

M_M = Class I RR MOW Material and Supply Expense

R_O = AAR Other Cost Index

M_O = Class I RR MOW Other Expense

This annual index was then calibrated with 2001 as the reference year (e.g., 2001 index = 100%, 1978 index = 36.22%) so that all expenses could be referenced in terms of relatively current prices. Maintenance of way nominal expenses and investments were then divided by each year's index to obtain constant 2001 dollars.

2.3.2 Defining Maintenance Cost and Renewal Strategy

Gross Ton Miles and Track Miles are standard units of measurement for U.S. railroads. Gross Tonnage is the total weight of all locomotives, rail cars, and lading that pass over a particular location, and a gross ton mile is one gross ton moving over one mile of track. Unit maintenance cost was defined as the unit cost of maintaining track, that is, ordinary maintenance expenses plus renewal-based capital expenditures per million gross ton miles produced by railroads.

$$C_M = (E_O + C_R) / Q$$

where:

C_M	=	Unit Maintenance Cost (cost per MGTM)
E_O	=	Ordinary Maintenance Operating Expense
C_R	=	Renewal Capital Expenditures
Q	=	Million Gross Ton Miles (MGTM)

Renewal strategy was defined as the percentage of total maintenance costs that were allocated to renewal capital expenditures.

$$RS = C_R / [(E_O + C_R)\ 100]$$

where:

RS	=	Renewal Strategy

2.3.3 Estimating Renewal-based Capital Expenditures

Because railroad cost accounting systems do not itemize renewal capital expenditures, renewal capital expenditures were estimated by comparing the annual percentage of ties and rail laid in replacement track to the total amount of ties and rail laid. Railroad financial reports distinguish between ties and rail "laid in replacement track" vs. "laid in additional track" from AAR reports (Lines 344-372) (AAR 1978-2002a). Although there are other aspects of the annual capital program, the largest portion of capital is for rail and ties (both purchase and installation). An additional step was taken to differentially weight rail and tie percentages because, on average, capital programs normally allocate a slightly higher budget for ties than for rail.

A similar method of estimating the renewal portion of the railroad capital budget using ratios of ties laid in replacement to total ties laid was first used by Ivaldi and McCullough (2001), but their method did not consider rail laid in replacement or addition.

Railroad financial data segregates capital investment for Road Communications, Road Signals & Interlocker, and Road Other, with the majority of investment categorized as Road Other. I assumed that capital expenditures for Signals and Communications Systems were primarily for new technology and major system upgrades such as replacing extant wire and relay based systems with fiber optic, wireless, and digital technologies, and were appropriately classified as additions.

Renewal Capital Expenditures were calculated as follows:

$$P_T = T_E / (T_E + T_N)$$

where:

P_T	= Percentage Renewal Tie Program
T_E	= Number of Ties Laid In Existing Track
T_N	= Number of Ties Laid In New Track

$$P_R = R_E / (R_E + R_N)$$

where:

P_R	= Percentage Renewal Rail Program
R_E	= Tons of Rail Laid in Existing Track
R_N	= Tons of Rail Laid in New Track

$$P = [(0.6\ P_T) + (0.4\ P_R)]$$

$$C_R = C_O \cdot P$$

where:

C_O	= Road Capital Other
P	= Overall Percent Renewal

2.3.4 Railroad Groupings

The number of railroads reporting financial and operating data (in R1 standard format to the AAR) declined from 36 in 1978 to eight in 2001. Most of this reduction occurred through mergers and combinations, although there were also bankruptcies and deletions by changes in Class I railroad definition. Individual railroad data were combined into their 2001 industry structure (Table 2.3).

Table 2.3: Railroad Data Groupings

Railroad Group	Individual Railroads and Years in which they were individually listed in AAR Reports
Union Pacific (UP)	Union Pacific Railroad (1978-2002) Missouri Pacific Railroad (1978-1985) Western Pacific Railroad (1978-1985) Missouri-Kansas-Texas Railroad (1978-1988) Chicago North Western (1978-1994) Southern Pacific Railroad (1978-1996) St Louis Southwestern Railroad (1978-1989) Denver & Rio Grande Railroad (1978-1993)
Burlington Northern Santa Fe (BNSF)	Burlington Northern Santa Fe (1996-2002) Burlington Northern Railroad (1978-1995) Colorado Southern Railroad (1978-1981) Ft Worth & Denver Railroad (1978-1981) Atchison Topeka & Santa Fe Railroad (1978-1995) St Louis San Francisco Railroad (1978-1980)
CSX (CSX)	CSX (1986-2002) Baltimore & Ohio Railroad (1978-1985) Chesapeake & Ohio Railroad (1978-1985) Western Maryland Railroad (1978-1983) Seaboard Coast Line (1978-1985) Louisville & Nashville Railroad (1978-1982) Clinchfield Railroad (1978-1982)
Norfolk Southern (NS)	Norfolk Southern (1986-2002) Norfolk & Western Railroad (1978-1985) Southern Railway (1978-1985)
Kansas City Southern Railroad (KCS)	Kansas City Southern (1978-2002)
Illinois Central Railroad (IC)	Illinois Central (1988-2001) Illinois Central Gulf (1978-1987)
SOO (SOO)	SOO (1978-2002)
Grand Trunk Western (GTW)	Grand Trunk Western (1978-2001) Detroit Toledo & Ironton (1978-1983)

The one major exception to this is the division of Conrail into CSX and NS in 1999. In 2002, the Grand Trunk Western and the Illinois Central were combined with other Canadian National Railroad lines in the U.S.

Railroads excluded from these groupings but included in the overall Class I statistics are:

- Conrail
- Milwaukee
- Bessemer & Lake Erie
- Duluth, Missabe, & Iron Range
- Elgin Joliet & Eastern
- Florida East Coast
- Long Island
- Pittsburgh and Lake Erie
- Delaware and Hudson

2.4 Renewal Strategy as a Single Independent Variable

The study period (1978-2002) was divided into five year increments beginning in 1978 with the last period (1999-2002) being a four-year increment. Each component (renewal capital expenditures, ordinary maintenance operating expense, MGTM) was averaged over each time period for each railroad. The model tested was:

$$\text{Model 2.1:}\quad C_M = a + b\text{RS} + \varepsilon$$

where:

C_M = Unit Maintenance Cost ($ per MGTM)

a = Intercept

b = Coefficient for RS

RS = Renewal Strategy

ε = error term

Renewal strategy and unit (infrastructure) maintenance cost were calculated for each railroad over each time period (Table 2.4). Data for IC and GTW did not include

2002 due to consolidation with CN. Data for all Class I railroads in the United States were aggregated and labeled (US).

Table 2.4: Comparison of Renewal Strategy and Unit Maintenance Cost

Road	Renewal Strategy					Unit Maintenance Cost				
	'78-'82	'82-'87	'88-'92	'93-'98	'99-'02	'78-82	'82-87	'88-92	'93-'98	'99-'02
US	15.2%	44.4%	41.9%	50.0%	52.7%	5,803	4,737	3,499	2,589	2,207
UP	17.2%	48.1%	47.4%	55.7%	64.0%	4,885	4,537	3,140	2,149	1,933
BNSF	16.6%	44.8%	34.7%	55.1%	62.9%	4,966	3,982	2,908	2,450	1,848
CSX	13.2%	41.5%	40.8%	39.4%	41.3%	6,349	4,815	3,376	2,453	2,701
NS	16.5%	40.0%	44.2%	45.4%	34.6%	5,167	5,529	5,011	3,539	3,207
IC	16.4%	45.6%	58.0%	74.4%	67.2%	7,330	3,520	2,118	2,297	2,041
KCS	17.5%	44.8%	48.6%	52.8%	55.6%	6,659	4,329	4,543	3,629	2,869
SOO	10.5%	21.6%	35.2%	38.1%	39.8%	7,228	4,730	3,985	4,224	3,029
GTW	11.8%	20.8%	24.0%	29.1%	53.7%	7,747	5,115	5,159	4,035	2,520

A series of linear regressions were conducted for each time period with renewal strategy as the independent variable and unit maintenance cost as the dependent variable (Model 2.1). The results indicate that there was a statistically significant relationship only for the last time period, with an R^2 of 0.80, a *p* value of 0.003, and F/F_c of 3.96 with F_c calculated at a 95% confidence level (Table 2.5).

Table 2.5: Influence of Renewal Strategy on Unit Maintenance Cost

Period	R^2	F/F_c	*p*	*a*	*b*
1978 – 1982	0.38	0.62	0.103	10,188	-26,053
1983 – 1987	0.23	0.30	0.230	5,639	-2,784
1988 – 1992	0.28	0.39	0.175	6,075	-5,515
1993 – 1998	0.44	0.80	0.072	5,063	-4,032
1999 – 2002	0.80	3.96	0.003	4,496	-3,773

Comparison of the five periods indicates improving correlation over time with the strongest correlation in 1999-2002. The only period with an *F*-test that indicated significance was 1999-2002.

A plot of the data from the last period (1999-2002) along with the regression trend line is shown in Figure 2.4.

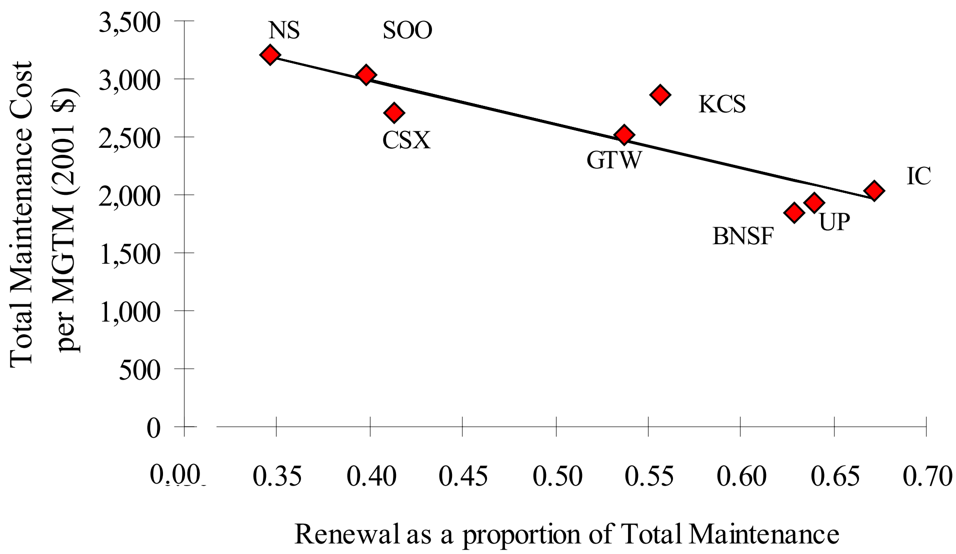

Figure 2.4: Relationship of renewal strategy and maintenance cost, 1999-2002

2.5 Alternative Hypothesis: Influence of Size

An alternative hypothesis is that network size as measured in track miles is responsible for the variation in unit maintenance cost. A statistical test was conducted comparing the original model to one including a size variable as measured by track miles (TM). The results indicate that while railroad size was a statistically significant variable, it had far less influence than renewal strategy on maintenance cost. The results suggest that (a) a 10% increase in track miles for the average railroad (equal to an additional 2,091 track miles in 2001) would result in a reduction of $18 per MGTM total maintenance cost, and (b) an increase of 10% in renewal strategy would result in a reduction of $369 per MGTM total maintenance cost, or a 12-18% cost reduction depending on the individual railroad. Furthermore, the results suggest that the track mile variable was significant only in combination with renewal strategy (at the 95% confidence level). The analysis is described in additional detail in the appendix.

Two plausible explanations exist for the size effect. First, larger railroads may have been slightly more cost effective in their maintenance programs because they could employ renewal systems more effectively. This could have resulted from more productive use of specialized equipment, by optimizing component renewal cycles for any given piece of track, and/or by having more options to detour traffic thereby permitting longer track possession windows. A second explanation for this effect is that there may have been a quasi-fixed overhead (engineering) cost associated with maintaining infrastructure regardless of railroad size.

2.6 Alternative Hypothesis: Influence of Light Density Track Miles

An alternative hypothesis is that light density lines are responsible for the variation in unit maintenance cost between railroads. Class I railroads had reduced the number of low density routes through sale, abandonment, or lease in order to reduce the amount of low performing routes. According to current economic theory, each track mile has a quasi-fixed cost associated with it that includes a maintenance-related component, and those roads that were able to shed more of these low density lines may have had an inherent cost advantage. A statistical test was conducted comparing the original model to one including a variable for the percentage of light density track miles (D_L). Light density track was defined, for these purposes, as track with less than 10 million gross ton-miles per mile per year and was based on Bureau of Transportation Statistics data from 2000 (U.S. DOT 2001). This analysis is described in detail in the appendix. Results indicate that the percentage of light density track miles was not a statistically significant variable in the determination of unit maintenance cost.

2.7 Alternative Hypothesis: Influence of Average Density

Another alternative hypothesis is that average density is responsible for the variation in maintenance cost between railroads. This hypothesis is also related to the theory that each track mile has a quasi-fixed maintenance cost. A statistical test was conducted comparing the original model to one including a variable for average density as measured in MGTM per Class I Railroad track mile (Line 343 AAR reports). This analysis is described in the appendix. Results indicate that while average density (D_A) improved the model slightly and was statistically significant at a 94% level of confidence, it had less influence than renewal strategy with respect to maintenance cost. The results suggest that (a) a 10% increase in average track density (equal to an additional 1.8 MGTM per track mile in 2001) would result in a reduction of $74 per MGTM total maintenance cost, and (b) an increase of 10% in renewal strategy would result in a reduction of $312 per MGTM total maintenance cost. Furthermore, the analysis suggests that average density was significant only in combination with renewal strategy.

2.8 Combining Statistically Significant Variables

Comparison of the two models to predict unit maintenance cost, that is, renewal strategy and size, renewal strategy and density, indicated that they were virtually equal in terms of statistical significance with sum of squared errors (SSE) of 181,140 and 175,880, respectively. A final test was conducted combining renewal strategy, average density and size. This combined three-variable model resulted in a SSE of 114,873, but because of fewer degrees of freedom, the three-variable model was statistically superior only at an 82% level of confidence. The regression estimates for the variable coefficients are shown below.

$$C_M = 4{,}789 + (-3{,}288\ RS) + (-26.9\ D_A) + (-0.0056\ TM) + \varepsilon$$

The analysis also indicated that the correlation coefficient (R^2) was 0.94 and that the RS variable was more precise (p = 0.0049) in comparison to D_A (p = 0.20) or TM (p = 0.22) variables.

2.9 Discussion

Three questions arise from the analysis:

- Why is a renewal strategy cost effective?
- How do these findings compare with other studies?
- Why was this relationship significant only in the most recent period?

As previously described, large mechanized track gangs are more productive not only in terms of labor and materials, but with use of limited track possession time. Their work is better planned and executed due to engineering management systems. The work can be programmed in advance so that traffic patterns can be adjusted to provide long track possession windows that maximize resource productivity.

It also appears that an emphasis on reducing ordinary maintenance expense was important. I compared ordinary maintenance expense and renewal capital expenditures per MGTM for the four time periods between 1982 and 2002 for each railroad (Table 2.6).

Table 2.6: Comparison of Ordinary Maintenance Expense and Renewal Capital Expenditures per MGTM (constant 2001 $'s)

	Ordinary Maintenance Expense per MGTM				Renewal Capital Expenditures per MGTM			
Road	'82-'87	'88-'92	'93-'98	'99-'02	'82-87	'88-92	'93-'98	'99-'02
US	2,638	2,037	1,306	1,044	2,108	1,467	1,298	1,163
UP	2,365	1,660	958	698	2,181	1,491	1,201	1,239
BNSF	2,202	1,899	1,131	686	1,787	1,010	1,353	1,163
CSX	2,829	2,004	1,493	1,586	2,007	1,375	970	1,113
NS	3,319	2,801	1,949	2,100	2,210	2,213	1,608	1,115
IC	1,887	889	591	669	1,654	1,226	1,707	1,372
KCS	2,389	2,341	1,735	1,273	1,951	2,206	1,947	1,605
SOO	3,869	2,590	2,604	1,835	1,207	1,389	1,629	1,213
GTW	4,057	3,927	3,031	1,165	1,087	1,239	1,177	1,370

Some railroads made greater reductions in ordinary maintenance expense than others. Other than average density and system size, there were no obvious characteristics that appeared to offer a satisfactory alternative explanation for overall maintenance cost other than renewal strategy. Although there was some appearance of an east-west geographic effect for the large roads, results for smaller roads were not consistent with it and I am not aware of any apriori reason for such an effect.

The renewal, density and size effects were fairly intuitive from an engineering viewpoint and consistent with available studies. The renewal strategy effect was consistent with International Union of Railways (2002) studies indicating a beneficial effect of renewal in reducing total maintenance costs. The density effect was consistent with a number of statistical studies that find economies of density (Braeutigam et al. 1984; Caves et al. 1985; Barbera et al. 1987; Lee and Baumol 1987; Dooley et al. 1991). These studies differ as to the significance of the density effect, however. Braeutigam and Caves found significant density effects, Lee found considerably smaller density effects than in previous studies, and Dooley found only moderate returns to density. The size effect was consistent with Caves' findings of slightly increasing returns to scale, but was not consistent with Barbera or Lee who found constant returns to scale. The results of this study, which focused solely on infrastructure maintenance cost, are generally consistent with many of these econometric studies that considered a broader range of transportation costs than I did.

A complete response to the third question is less intuitive in part because track renewal systems have been employed by railroads for many years, but involves a combination of the following points:

1. The relationship would not have been apparent in the period prior to depreciation accounting (1978 to 1982) because a large portion of renewal costs were accounted for as ordinary maintenance operating expense due to betterment accounting rules in effect during that period.
2. Delivery and information systems and planning technology have continued to improve in recent years increasing the relative efficiency of renewal-based maintenance in relation to ordinary maintenance.

3. The unit cost differences between ordinary and renewal-based maintenance may not have been statistically apparent until reductions in ordinary maintenance gangs were fully realized to their present level.
4. Increasing train densities may have increased the relative cost effectiveness of renewal-based maintenance. From 1978 to 1987 average train density increased by less than 1% per year; from 1988 to 2001 train density increased by almost 6% per year. Reduction of light density track through sale or abandonment may also have had an effect on the statistical relationships.
5. The railroads were consolidating to fewer and larger networks.

In summary, the results indicate that most of the variation in unit maintenance costs among Class I railroads can largely be explained by variation in the degree to which they emphasize renewal and de-emphasize ordinary maintenance in their engineering strategies. Baseline ordinary maintenance cost was estimated for each railroad (Table 2.7).

Table 2.7: Estimation of Baseline Ordinary Maintenance Expense excluding effects of Renewal Strategy (including Density and Size effects) (1999-2002)

Road	Maintenance Cost ($s) per MGTM	Renewal Strategy	Average Density MGTM/TM	Track Miles	Baseline Expense per MGTM
UP	$1,933	64.0%	21.7	48,005	$4,038
BNSF	$1,848	62.9%	22.9	42,055	$3,917
CSX	$2,701	41.3%	14.0	34,006	$4,060
NS	$3,207	34.6%	11.9	31,645	$4,346
IC	$2,041	67.2%	12.6	3,901	$4,249
KCS	$2,869	55.6%	10.2	3,882	$4,699
SOO	$3,029	39.8%	15.7	2,777	$4,339
GTW	$2,520	53.7%	19.1	1,392	$4,287

The baseline ordinary maintenance cost was calculated assuming that renewal maintenance was eliminated altogether (100% ordinary maintenance), but allowed for both density and size effects. The railroads fell into three groups in terms of baseline expense per MGTM: UP, BNSF, and CSX (between $3,917 and $4,060 per MGTM); NS, IC, SOO and GTW (between $4,249 and $4,346 per MGTM), and KCS ($4,699 per MGTM).

This analysis necessarily made the supposition that rail infrastructure quality for each road over each time horizon was not trending strongly in one direction or the other. This is related to the supposition that gross ton miles produced in one period were generally equivalent to gross ton miles produced in another period. These suppositions are rarely true in absolute terms, but for a given class of track, track conditions can only vary within a pre-determined range.

Although a distinction was made between costs for capacity expansion and maintenance, capacity and maintenance cost are not entirely independent. As train densities increase, track possessions for maintenance may become limited in duration and frequency because track gangs must compete with trains for track time. Consequently, capacity limitations increase unit cost because of the more frequent need for gangs to get on and off track. Capacity expansion may thus have a secondary effect of decreasing unit maintenance cost.

This analysis focused only on maintenance costs. An important consideration for any railroad is the effect that different maintenance strategies have on transportation costs and service quality. My initial tests were inconclusive in this regard, probably because of more influential effects of factors not related to maintenance, for example reduction of crew size, changes in transportation labor work rules, and improvements in motive power efficiency.

This analysis is only valid for the range of data presented. Extending it beyond the limits of demonstrated values may lead to inappropriate conclusions. As mentioned previously, a 100% renewal strategy is neither attainable nor desirable based on current technology or maintenance and accounting practices. This analysis is intended for use by railroad engineering professionals as one tool (of many) in the determination of the appropriate balance between ordinary and renewal maintenance options.

Two final questions are proposed for further research and discussion. First, what are the real limits of cost efficiencies generated by renewal strategies? If UP, BNSF and IC can achieve renewal levels in the 60 percent range, would a further shift from operating expense to renewal investment result in even lower unit cost? Second, what barriers exist for other roads, such as CSX, NS, and SOO, from gaining the apparent benefits of shifting more ordinary maintenance to renewal regimes? Could these barriers be technical (i.e. infrastructure characteristics), financial (i.e., tight capital or expense budgets), philosophical (i.e., safety, management), operational (i.e., train densities), or a combination?

2.10 Conclusions

The results are consistent with the hypothesis that an emphasis on renewal programs for track maintenance was cost effective from an engineering viewpoint and provided an explanation of why railroads have consistently increased capital expenditures for renewal maintenance. Additionally, the intrinsic cost of maintaining railroad infrastructure does not vary substantially among Class I railroads and apparent differences in unit maintenance costs can be explained by the degree to which individual firms apply renewal strategies.

2.11 Appendix

2.11.1 Maintenance Cost and Capital Expenditures: Alternative Hypothesis, Influence of Size

A statistical test was conducted comparing the models shown below:

Model 2.1: $C_M = a + b\text{RS} + \varepsilon$

Model 2.2: $C_M = a + b\text{RS} + c\text{TM} + \varepsilon$

where:

C_M = Unit Maintenance Cost ($ per MGTM)

a = Intercept

b = Coefficient for RS

RS = Renewal Strategy

c = Coefficient for TM

TM = Track Miles

ε = error term

Test results (Tables 2.8 and 2.9) indicated that Model 2.2 was statistically preferable to Model 2.1. The adjusted R^2 statistic (adjusted R^2) indicated improved correlation and the *F*-test indicated improved significance of results. *T*-test results indicated that renewal strategy was a more significant variable in combination with the track miles. The *t*-statistic for the track miles variable was significant, and intercept and slope coefficients all appeared reasonable. Furthermore, comparison of the sum of squared errors for the two models indicated that they were statistically different (F/F_c = 1.00 at $\alpha = 0.1$ or a 90% level of confidence).

The results of the joint hypothesis test did not allow me to reject Model 2.2 in preference to Model 2.1. In other words, track miles was a useful explanatory variable in estimating maintenance cost. A comparison of *p* values indicated that the influence of the renewal strategy variable was much greater than the track mile variable in the estimation of maintenance cost.

Table 2.8: Statistical comparison of Models 2.1 and 2.2

	Overall Model Results			Renewal Strategy		Track Miles	
Model	Adjusted R^2	F/F_c	*a*	*b*	*p*	*c*	*p*
2.1	0.76	3.96	4,496	-3,773	0.0028		
2.2	0.87	4.12	4,636	-3,695	0.00144	-0.0086	0.06325

Table 2.9: Joint Hypothesis Test of Models 2.1 and 2.2

F	Observations	New Parameters	F/F_c	*p*	Result
6.7911309	8	1	1.02773	0.03133	Do Not Reject Model 2.2

The OLS regression yielded the following estimates for the variable coefficients:

$$C_M = 4{,}636 + (-3{,}695\ RS) + (-0.0086\ TM) + \varepsilon$$

Another regression was conducted to test the relationship of railroad size (e.g., track miles) and unit maintenance cost without the influence of a renewal strategy variable (see Model 2.3).

Model 2.3: $C_M = a + b\mathrm{TM} + \varepsilon$

Test results indicated weak correlation ($R^2 = 0.15$, adjusted $R^2 = 0.005$) and insignificant results ($F/F_c = 0.17$) and this model was rejected.

2.11.2 Maintenance Cost and Capital Expenditures: Alternative Hypothesis, Influence of Light Density Track Miles

A statistical test was conducted comparing the models shown below:

Model 2.1: $C_M = a + b\mathrm{RS} + \varepsilon$

Model 2.4: $C_M = a + b\mathrm{RS} + cD_L + \varepsilon$

where:

D_L = Percentage of light density track miles (< 10 MGTM per mile per year)

The percentage of light density track miles was calculated from the *National Transportation Atlas Database* (U.S. DOT 2001).

Although the adjusted R^2 statistic indicated improved correlation, *F*-test results indicated that Model 2.4 was less significant than Model 2.1 (Tables 2.10 and 2.11). *P* values indicated that D_L was not an influential factor.

Table 2.10: Statistical comparison of Models 2.1 and 2.4

	Overall Model Results			Renewal Strategy		Percent Light Density	
Model	Adjusted R^2	F/F_c	*a*	*b*	*p*	*c*	*p*
2.1	0.76	3.96	4,496	-3,773	0.0028		
2.4	0.81	2.69	3,709	-3,472	0.0051	1606	0.1901

Table 2.11: Joint Hypothesis Test of Models 2.1 and 2.4

F	Observations	New Parameters	F/F_c	*p*	Result
2.7550568	8	1	0.41694	0.13553	Reject Model 2.4

The results allowed me to reject Model 2.4 in preference to Model 2.1. In other words, the percentage of light density track miles was not a useful explanatory variable in estimating unit maintenance cost.

A final regression test was conducted to test the relationship of light density track and unit maintenance cost without the influence of a renewal strategy variable (see Model 2.5).

Model 2.5: $C_M = a + bD_L + \varepsilon$

The results indicated weak correlation ($R^2 = 0.24$, adjusted $R^2 = 0.11$) and insignificant results ($F/F_c = 0.22$) and this model was rejected.

2.11.3 Maintenance Cost and Capital Expenditures: Alternative Hypothesis, Influence of Average Density

A statistical test was conducted comparing Model 2.1 to Model 2.6 shown below:

Model 2.1: $C_M = a + b\text{RS} + \varepsilon$

Model 2.6: $C_M = a + b\text{RS} + c\text{D}_A + \varepsilon$

where:

D_A = Average Density (MGTM per track mile)

The results (Tables 2.12 and 2.13) indicated that Model 2.6 was statistically preferable to Model 2.1. The adjusted R^2 statistic indicated improved correlation, the *F*-test results indicated that Model 2.6 was more significant than Model 2.1. *P* values indicated that average density was an influential variable, but not as significant as the renewal strategy variable.

Table 2.12: Statistical comparison of Models 2.1 and 2.6

	Overall Model Results			Renewal Strategy		Average Density	
Model	Adjusted R^2	F/F_c	*a*	*b*	*p*	*c*	*p*
2.1	0.76	3.96	4,496	-3,773	0.0028		
2.6	0.87	4.26	4,802	-3,117	0.0044	-40.56	0.0582

The results of the joint hypothesis test did not allow me to reject Model 2.6 in preference to Model 2.1. In other words, average density was a useful explanatory variable in estimating unit maintenance cost in combination with renewal strategy.

Table 2.13: Joint Hypothesis Test of Models 2.1 and 2.6

F	Observations	New Parameters	F/F_c	*p*	Result
7.17372	8	1	1.08563	0.028	Do Not Reject Model 2.6

A regression test was conducted to test the relationship of average density and unit maintenance cost without the influence of renewal strategy (see Model 2.7).

Model 2.7: $C_M = a + bD_A + \varepsilon$

The results indicated weak correlation ($R^2 = 0.46$, adjusted $R^2 = 0.37$) and insignificant results ($F/F_c = 0.85$) and this model was rejected.

3.0 Railway Output and Infrastructure Capital Expenditures

"The increase in total costs resulting from an expansion in a firm's volume of business is commonly referred to as incremental cost."

William Baumol, 1962

"The application of these cost concepts by the railroad industry and the ICC has concentrated on the use of accounting data sources and therein lies the problem."

James Kneafsey, 1975

This chapter evaluates and estimates the degree to which changes in railway output affect annual railway infrastructure capital expenditures. This relationship is central to economic concepts of marginal and variable cost in an industry heavily dependent on continuing annual capital expenditures. These economic concepts, in turn, are important to both commercial pricing decisions and external economic regulation that affect the financial viability of the industry. The focus on infrastructure in this chapter, as opposed to rolling stock, is made because it is with respect to infrastructure capital expenditures that questions arise regarding their consideration as a marginal cost. Rolling stock investment has long been considered variable with traffic (ICC 1943) and recent studies continue to treat equipment costs as variable with output (Ivaldi and McCullough 2001).

Following deregulation in 1980, Class I railroads began a period of long-run investment growth and, except for distortions caused by the Economic Tax Recovery Act of 1981, infrastructure capital expenditures grew at about the same rate as output (Figure 3.1) (AAR 1978-2002a). This included capital expenditures for track (rail, ties, surface and lining), structures (bridges, tunnels, buildings), signals and communication systems (fiber optics, dispatching systems, microwave and digital communications systems), facilities (yards, terminals), and new equipment and software. Because of the investment distortions caused by the tax act, and technical changes in the industry, most of the analyses presented in this paper focus on the period following 1987.

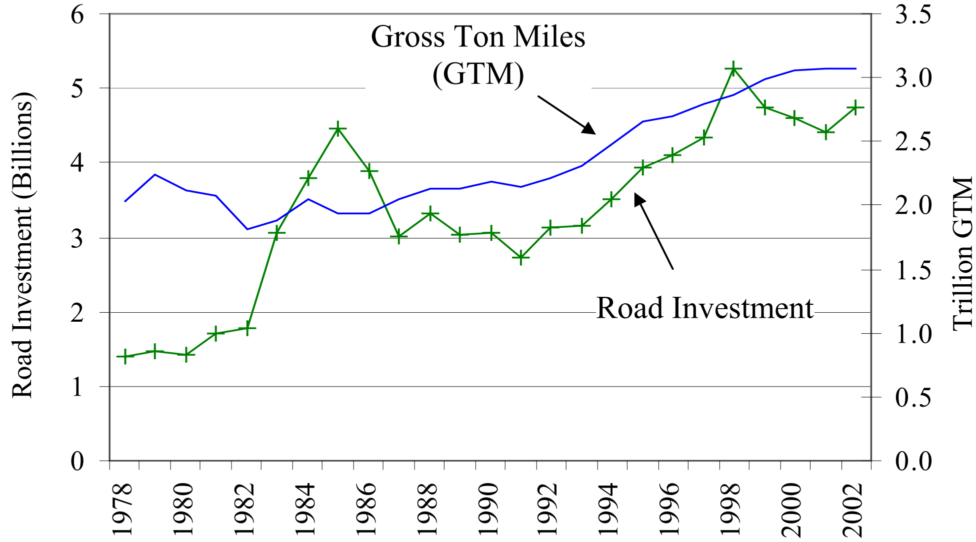

Figure 3.1: Class I Railroad Gross Ton Miles and Road Investment (2001 $s)
Source: AAR Analysis of Class I Railroads

Rail output continued to expand although growth was not uniform and the greatest increase in carload traffic was in intermodal traffic (Figure 3.2). The Association of American Railroads (AAR) data combines intermodal and miscellaneous boxcar traffic.

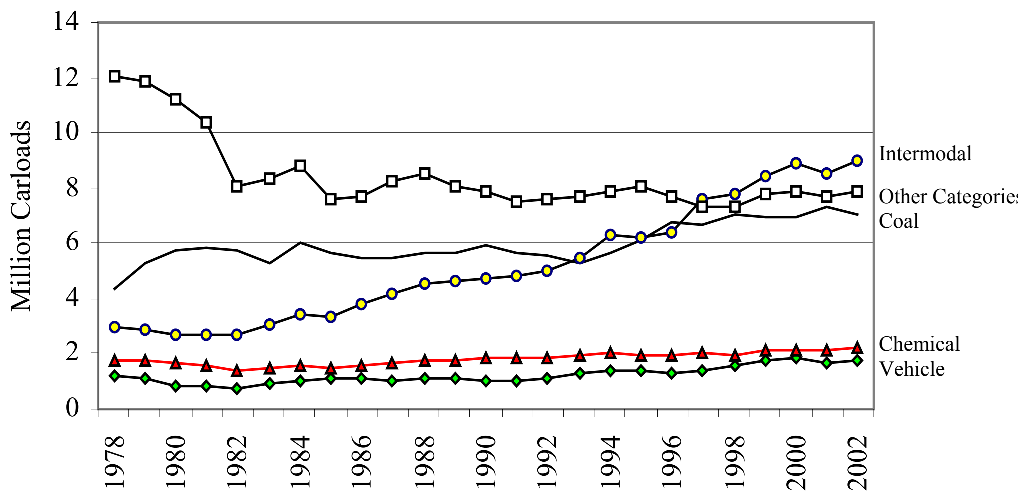

Figure 3.2: Class I Railroad Carloads by Commodity Group
Source: AAR Analysis of Class I Railroads

On a tons originated basis, the largest growth was in coal (Figure 3.3).

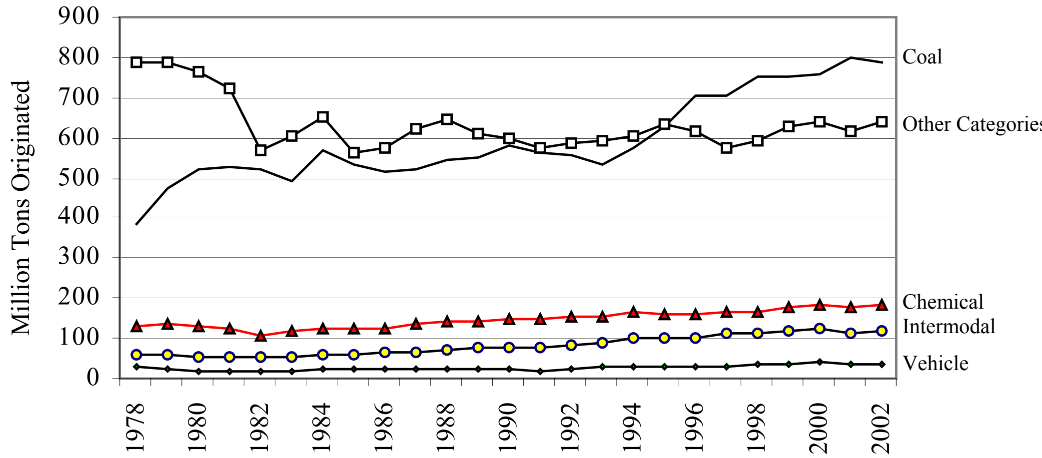

Figure 3.3: Class I Railroad Tons Originated by Commodity Group
Source: AAR Analysis of Class I Railroads

According to congressional testimony, railroads require more capital expenditures, as a percentage of revenue, than any other major industry sector, and far greater than any other transportation mode (U.S. Congress House Committee 1998, 125-26). From 1988 to 2002, the industry's annual capital expenditures averaged over 16% of revenues. Railroads normally require about three times as much capital as the average S&P (Standard and Poors) industrial company. As a result, it is particularly important to railroads and their economic regulators that the relationship between capital expenditures and output be properly defined so that capital expenditures are correctly reflected in marginal and variable cost estimates. Marginal and variable cost estimates serve as a foundation for internal price decisions and for economic regulation. Even small but systematic miscalculations can result in significant financial losses. For example, if actual marginal costs are under-estimated, contribution ratios will be overstated and a decision to trade a slight reduction in price for a slight increase in volume may result in unintended and unobservable losses to the firm. Or, if the Surface Transportation Board

(STB) under-estimates average variable cost used to establish the regulatory oversight threshold, it might subject a larger share of traffic to economic regulation than would otherwise occur.

A recent study by the American Association of State Highway and Transportation Officials (AASHTO) estimates that without continued investment at a rate consistent with transportation demand, shippers, taxpayers, and highway users will face additional costs in the range of $400-$800 billion over the next 20 years for additional road maintenance and congestion related delays (AASHTO 2002, 2-3). Concerns are emerging about the industry's capacity to continue to invest sufficiently to accommodate rising transportation demand. Shippers have recently complained to Congress about tightening capacity in the rail system (U.S. Congress House Committee 2001, 34-5). Financial analysts have highlighted the low returns to rail investment and recommended constraints on capital and capacity investments (Flower 2003a; Flower 2003b; Gallagher 2004). AASHTO (2002, 92) described the dilemma that railroads face: "To increase profitability, and to adapt to capital and capacity constraints, railroads are examining market segments not just for their contribution, but for their lost opportunity costs as well, and are de-marketing the least attractive traffic. Some carriers are considering … the elimination of … whole lines of business."

An informed discussion of revenue and price adequacy requires an understanding of the variability of capital expenditures in both short-run and long-run time horizons. The most recent empirical estimate of investment variability dates back to 1939 and the development of Rail Form A (RFA) by the Interstate Commerce Commission's (ICC's) Section on Cost Analysis. ICC studies on variable costs conducted in 1948, 1954, and 1963 all referred to the original 1939 study on the subject of investment variability, and did not recommend revisions (ICC 1948; ICC 1954; ICC 1963). Even the extensive studies conducted for the Uniform Rail Costing System (URCS) in the 1980's and 1990's addressed only the variability of expenses and did not consider investment as a variable cost (ICC 1982; Westbrook 1988; AAR 1991). Academic studies of railroad costs have not revisited the fundamental topic of investment variability as such, and focused on other issues such as economies of scale and density, productivity and capacity effects (Friedlaender 1969; Griliches 1972; Sidhu and Due 1974; Keeler 1974; Harris 1977;

Brown et al. 1979; Wilson 1980; Caves et al. 1980; Caves et al. 1981; Braeutigam et al. 1984; Caves et al. 1985; Barbera et al. 1987; Lee and Baumol 1987; Oum and Tretheway 1988; Dooley et al. 1991; Oum et al. 1998; Waters and Tretheway 1998; Bitzan 1999; Bitzan 2000; Mancuso and Reverberi 2003).

Gomez-Ibanez (1999) warned that short-run and long-run costs may appear different than they really are, implying that ongoing investment costs are more variable than they appear.

> [Railroad] congestion may be higher, capacity less lumpy, and sunk costs smaller than they first appear, with the result that short-run marginal cost may not be so different from long-run marginal cost … Beware of arguments that marginal costs are very different from average costs.

Conditions under which railroads operate and invest have changed substantially since deregulation in several ways that suggest revisiting this issue:

- Traffic levels have increased and track miles have decreased (from abandonments and sale of low-density track),
- maintenance methods have become more investment intensive,
- railroads gained more decision-making authority over their commercial environment, for example, price setting, contracting authority, abandonments, operating conditions, etc., and
- the rail industry switched from betterment to depreciation accounting in 1983.

To test the hypothesis that infrastructure capital expenditures are variable with and caused by output, meaning that they should be considered in marginal cost calculations, a series of lag specification and causality tests were used. Granger causality tests evaluate whether one variable influences or "causes" change in another variable by determining whether lagged information on one variable has any statistically significant role in explaining the other variable (Berndt 1991, 381). Lag specification tests determine which and how many lags are important in the causality analysis. Vector Auto Regression Granger Causality Wald tests are a more recent addition to causality analysis. The decision criterion for accepting or rejecting the hypothesis was: Do causality tests indicate that railroad output "causes" infrastructure capital expenditures? If yes, then capital expenditures can be interpreted as a marginal cost of output. If not, then the hypothesis is rejected.

3.1 Historical Studies of Railroad Investment Variability

Historical estimates of the variability of capital investment diverged widely, but most experts found it variable to some degree. Lorentz (1915, 218) believed that both operating costs and capital costs were variable with traffic. Miller (1925) found that, from 1902 to 1923, property investment was 74% variable with traffic volume. Healy (1940, 197) expressed the view that over a wide range of densities, the costs of handling additional increments of business were not likely to be much below average costs. Daggett (1941, 314-19) believed that capital investment was variable in both expansion and contraction of railroad business. Edwards showed that from 1923 to 1929 investment was 200 percent variable with ton mile growth (ICC 1943).

In 1939, the ICC developed RFA to estimate rail costs for use in regulating rail rates (ICC 1943). In estimating "average variable cost", it included the variable portion of operating expenses, rents and taxes, plus a return on (aggregate) investment in rolling stock and the variable portion of (aggregate) road investment. The provision for a return on aggregate investment was only included in their calculation of average variable cost to account for the perspective that economic regulators must consider in order to ensure continued investment. The ICC's calculations did not include any portion of annual investment (or capital expenditures).

The ICC's original (1939) estimate of investment variability was derived from earlier industry data (1915 to 1932) that showed that total (infrastructure and rolling stock) annual investment was between 65% and 200% variable with traffic volume. The ICC assumed that rolling stock investment was 100% variable and decided that aggregate infrastructure investment "should be about 50% variable" (ICC 1941a). This (50%) was applied to the return on investment for infrastructure, which was then included in the calculation of RFA's "average variable cost."

The theory that the ICC should provide for a return on investment (to account for the long-run perspective) when regulating railway rates had been established previously. Merritt (1906, 16) stated that fair return on investment was required for future investment, “for if investors were to be deprived of the privilege of earning such returns, there would never be another mile of railway built in this country, which in the present state of our economy would be disastrous.” Locklin (1935, 130-31) pointed out that the cost of future capital depended on a return to capital: “(historic) capital must in the long run receive its reward, or additional capital will not be forthcoming when needed.”

The 1939 study also established variability estimates for a wide range of other costs that were applied to all railroads, regardless of size, density, territory, or other characteristics. The AAR, and a number of economists, criticized this “one-size-fits-all” method, citing the need to consider economies of density in cost functions (Meyer 1959; Healy 1961; Poole 1962; AAR 1964; Friedlaender 1969; Griliches 1972; Sidhu and Due 1974; Keeler 1974; Harris 1977). The ICC revisited its original 1939 study several times but continued to apply cost variabilities on a uniform basis (ICC 1948; ICC 1954; ICC 1963).

The ICC began development of URCS in 1977 following passage of the Railroad Revitalization and Regulatory Reform Act (4R Act). The purpose of URCS was to identify average or long-run variable costs more precisely than RFA and to estimate variabilities on an individual railroad basis. Research and development of URCS was completed by 1981, but it was not fully adopted until 1989 after further debate and additional study. URCS employed new estimates of cost variability for expenses, but treated investment in the same manner as RFA. The issue remained somewhat confused because URCS, as did RFA, mixes concepts of investment variability and return on investment, as well as concepts of variable and opportunity cost. The issue is further complicated by the inclusion of 50% of depreciation expense in URCS variable cost estimates.

In 1991, the AAR conducted research to address the most critical portions of the URCS Phase I techniques and variable cost procedures. Although this critique included detailed analysis of expense related accounts, it did not address the need to re-consider annual investment as a variable cost, nor did it suggest revision of the original 1939 estimate for variability of aggregate investment that was now imbedded within URCS (AAR 1991). The AAR used the ICC's convention of including 50% way and structures depreciation (AAR 1991, 40) stating that these expenses were "primarily reflective of accounting conventions rather than economic concepts most relevant to costing purposes."

Economic studies through the 1980's and 1990's differentiated economies of density from economies of scale using translog cost functions (Caves et al. 1980; Caves et al. 1981; Friedlaender and Spady 1981; Braeutigam et al. 1984; Caves et al. 1985; Barbera et al. 1987; Lee and Baumel 1987; Dooley et al. 1991; Oum et al. 1998). Most of the models used to estimate railroad cost functions yielded wrong signs for capital stock, implying that the shadow value of capital input was negative. Oum explained this by stating that there was a kink in the relationship between the annualized cost of capital and the quantity of capital to produce a given current output (Oum and Waters 1996). To solve this problem, Oum replaced capital stock (K) by a measure of service flow (from capital) as the argument in the variable cost function. Service flow was computed by multiplying capital stock by its utilization factor, reflecting an assumption that capital is intrinsically variable with output. Some economists concluded that capital expenditures were fixed in the short run (Lee and Baumol 1987). Ivaldi and McCullough (2001) proposed that infrastructure capital played a significant role in explaining variable costs, implying that renewal expenditures, which comprise the majority of infrastructure investment, should be considered variable with output.

3.2 Engineering Foundations of Variable Capital Expenditures

Investments in transportation infrastructure have traditionally been considered to come in large or "lumpy" increments (Starkie 1982a). Examples include a new lane for a highway or a second main line or yard for a railway. Although relatively small projects can easily be viewed as variable with output, it is the big lumpy projects that lead to a common misinterpretation of the actual degree of variability of capital expenditures for infrastructure.

Although individual capacity projects are often considerable in size and scale, they typically represent a relatively small portion of the overall capital budget. Even large projects normally represent only a small fraction of their ultimate size and are designed to grow incrementally with demand. For example, a new intermodal yard may cost as much as $200 million, but the initial capacity may be only a fraction of the ultimate design capacity. As demand grows, tracks, parking space, and facilities are added in smaller increments.

Engineering studies support the concept that capacity can be added in small or variable increments as demand changes. Starkie (1982a) connected engineering practice and economic theory and disputed the traditional assumption that transportation capacity is subject to pronounced lumpiness or indivisibilities. He demonstrated that highway capacity could be added in small increments, finding that although the number of lanes was normally used to estimate capacity, there were many other factors that should be considered. These included lane width, clearance from obstructions, shoulder level, horizontal and vertical alignment, auxiliary lanes, surface quality, and traffic control systems (stop signs, stop lights, automated signals, etc.). Such features could be added incrementally to match capacity to demand. He also found, contrary to traditional economic thought, that prices for transportation infrastructure were relatively inflexible in comparison to capacity adjustments.

What Starkie pointed out was that economic theory traditionally treats prices as flexible and easy to change. In reality, at least when the price charged is extracted by taxes, tolls, contracts, or regulated tariffs, price changes require long periods for review and approval. Traditional economic theory also considers capacity difficult to modify presuming that it comes primarily in large, expensive increments requiring long periods to construct. In reality, capacity is easy to adjust and changes are often made in small increments over short periods of time. Gomez-Ibanez (1999) also supported the concept: "[highway] capacity is less lumpy than it appears, making it easier to adjust investment levels…"

Similarly, railway capacity can be judiciously adjusted to match demand. Siding spacing, number of locomotives, train size distribution, train crew availability, signaling systems, dispatching policies, management of slow orders, and distribution of train speeds and priorities can all be employed to incrementally expand or contract capacity to a predetermined level. Lengthening or shortening the time horizon between renewal programs can also expand or contract capacity. As a result, there are many options to adjust the capacity of even a single route to the point where it matches demand, and large networks have even more options to fine-tune overall capacity to complement overall demand.

Railroads calibrate their capital expenditures to accommodate incremental traffic through incremental capacity improvements according to Haley (2003, II-54-55).

> The railroad capacity planning process is focused on analyzing existing and projected rail traffic and identifying "bottleneck" locations where the railroad can expand throughput with incremental investment. For example, one of the most basic steps a railroad can take to expand capacity is to modernize its signaling system by replacing a less sophisticated Track Warrant Control (TWC) or Automatic Block System (ABS) and hand-thrown switches with more advanced Centralized Traffic Control (CTC) and power switches. This is not an all-or-nothing process. Instead, CTC can be installed on portions of line, and the CTC territory can be extended as traffic growth warrants. Another step a railroad can take as traffic grows is to construct new sidings at appropriate locations to relieve bottlenecks. In time, as traffic grows, a railroad will add more and more sidings. If traffic continues to grow even further, a railroad will begin to connect those sidings to form stretches of double-track. This process allows a railroad to increase its investment in road property as demand increases.

3.3 Methodology and Decision Criteria

To determine if and to what degree infrastructure capital expenditures should be considered in marginal cost calculations, a series of procedures and tests were constructed (Figure 3.4).

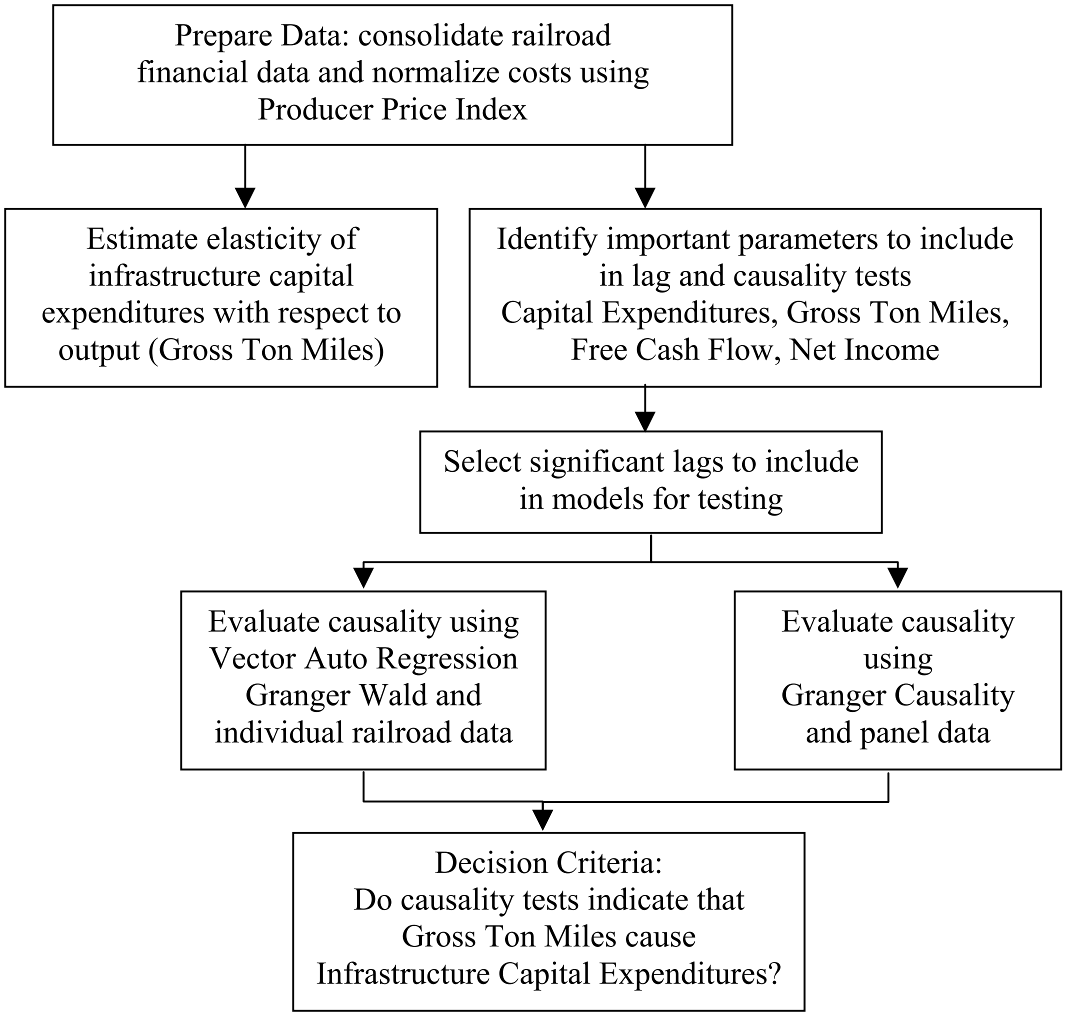

Figure 3.4: Decision analysis process

Industry financial data was consolidated and normalized to the Producer Price Index (PPI) as described in section 3.4. The elasticity of infrastructure capital expenditures was estimated as described in section 3.5. Additional parameters, free cash flow (FCF) and net income (NI), were tested to determine if they were significant in the prediction of capital expenditures using ordinary least squares (OLS) regression and standard *F*-tests (section 3.6). Lag specification tests determined (1) if lags were influential, and, (2) which lags were significant and would be included in the models. Granger causality tests were used to evaluate whether one variable influences or "causes" change in another variable by determining whether lagged information on one variable had any statistically significant role in explaining the other variable (Berndt 1991, 381). Lag specification and Granger causality analysis was first conducted to establish the relationship between road (infrastructure) capital expenditures (RI) and output (GTM) to determine if GTM caused RI and/or if RI caused GTM. These same procedures were then used to determine (1) if RI caused FCF and/or if FCF caused RI, and (2) if RI caused NI and/or if NI caused RI.

Additional confirmation and refinement of these relationships was developed using Vector Auto Regression Granger Causality Wald tests, a more recent addition to causality analysis. Vector Auto Regression (VAR) techniques are useful where the structure of a model is not clearly understood, including relationships between different variables and their lags. The VAR approach, originally proposed by Sims (1980), postulates that all variables in the system are endogenous and that each can be written as a linear function of its own lagged variables and the lagged values of all the other variables in the system. When all the variables are gathered into a single vector, the vector is expressed as a linear function of its own lagged values plus an error vector. VARs are usually estimated without restrictions and are considered a major methodological approach to econometrics (Kennedy 1998, 227).

The decision criterion for accepting the hypothesis that railroad output causes infrastructure capital expenditure was a causality test result that exceeded a 95% level of confidence. Specifically, if the *p* value from a Granger Causality Test of the influence of gross ton miles on capital expenditures was equal to or less than 0.05, then the hypothesis would be accepted.

3.4 Data Preparation

Because of significant consolidations in the railroad industry (from 36 Class I Railroads in 1978 to 8 in 2001), costs and output data are combined into railroad groups representing the 2001 industry structure consisting of 8 railroads: UP, BNSF, CSX, NS, KCS, IC, SOO, and GTW. These procedures are described in Chapter 2. Investment, Net Income and Free Cash Flow cost data were derived from the AAR Analysis of Class I Railroads (AAR 1978-2002a) and then normalized to 2001 using the Producer Price

Index. The PPI represents a group of investments that are roughly equivalent (in terms of risk level) to investment in railroad infrastructure. In other words, if railroad managers were looking for alternative investments (to railroad infrastructure) for available cash, such investments would more likely be made for producer type goods (therefore PPI) than for consumer type goods (CPI).

Net Income was broadly defined, in financial terms, as Total Revenues minus Total Expenses where expenses were defined according to cost accounting rules, including taxes and depreciation expense. For this analysis, Net Income was specifically defined as Net Railroad Operating Income in Line 5 of the AAR (1978-2002a) reports. Free Cash Flow was broadly defined as net income minus cash used for working capital and cash used in investing activities. For this analysis, Free Cash Flow was specifically defined as the sum of Net Cash provided from Operating Activities (Line 130) plus Net Cash Used in Investing Activities (Line 137) (AAR 1978-2002a).

Three time periods were selected for initial comparison because of distinct changes in economic conditions affecting rail investment in each of these periods. From 1978 to 1982, railroads were operating under betterment accounting rules in which track renewals were largely expensed. Beginning in 1983, railroads started using depreciation accounting rules under which most track renewal project costs were charged to investment accounts and subject to depreciation. From 1983 to 1987, railroads benefited from the Economic Recovery Tax Act of 1981 that allowed them to write off historical assets during this period. This act allowed railroads to depreciate up to forty percent of their asset base in one year (U.S. GAO 1981). This generated additional cash that was used mostly for infrastructure improvements to eliminate deferred maintenance that had accumulated in previous years. The greatest benefits were generated in the early years, creating an additional $2.5 billion in cash flow through 1985 (U.S. Congress Senate Committee 1987, 17). Following 1987, railroads continued to focus on cost reduction and productivity improvement with significant mergers including UP and CNW in 1994, BN and ATSF in 1995, UP and SP in 1996, and the division of Conrail between CSX and NS in 1998-1999 and others.

3.5 Gross Ton Miles as Single Independent Variable

OLS regression estimates were made for each road for each time period and F_c (F critical) was calculated at a 95% level of confidence. A value for the ratio of F/F_c equal to or exceeding 1.0 indicates significance. In addition to R^2 and *F*-tests, the sign and absolute value of the variable coefficients were used to evaluate results. The null hypothesis was that road investment was correlated with gross ton miles on a year to year basis. The initial model tested is shown below:

Model 3.1: $\ln(RI) = a + [b \ln(TGTM)] + \varepsilon$

where:

RI = Road Capital Expenditures (000s)

a = Intercept

b = Coefficient for ln(TGTM), elasticity

TGTM = Thousand Gross Ton Miles

ε = error term

The use of the ln-ln form of this model allowed me to directly find the elasticity of Road Capital Expenditures with respect to output from the coefficient (*b*), and the precision with which this coefficient is estimated (from the *p* value).

As described in the preceding section, the three time periods for analysis (1978-1982, 1983-1987, and 1988-2002) were selected because of their distinct and different characteristics in relation to railroad accounting procedures (implementation of depreciation accounting in 1983) and investment behavior (investment tax credits from 1983 through 1987). The statistical results for individual railroads for each of these periods appeared to support the rationale for this temporal grouping (Table 3.1).

Table 3.1: Road Capital Expenditures (000s) vs. TGTM

	1978-1982			1983-1987			1988-2002		
	F/Fc	*b*	*p*	F/Fc	*b*	*p*	F/Fc	*b*	*p*
US	0.092	-61%	0.4050	0.005	-58%	0.8365	**8.506**	88%	**0.0000**
UP	0.297	-186%	0.1813	0.004	44%	0.8600	**4.251**	73%	**0.0006**
BNSF	0.177	177%	0.2727	0.002	-44%	0.9079	**5.794**	156%	**0.0002**
CSX	0.169	385%	0.2824	0.066	-349%	0.4748	**4.348**	136%	**0.0006**
NS	0.021	-8%	0.6760	0.015	260%	0.7209	0.038	7%	0.6786
KCS	0.665	507%	0.0807	0.156	-959%	0.2974	0.162	86%	0.4001
IC	0.299	87%	0.1800	0.001	-21%	0.9140	**1.298**	166%	**0.0288**
SOO	0.044	-46%	0.5533	0.013	-7%	0.7396	0.018	27%	0.7753
GTW	0.373	645%	0.1472	0.465	-1430%	0.1183	**4.085**	113%	**0.0009**

For the period 1978 through 1982, the statistical results appeared fairly conclusive. *F*-tests did not indicate significance, and *p* values were all greater than 0.08 with the *p* value for all Class I roads combined (US) being 0.4050. The estimated elasticity (*b*) values varied substantially and some were negative.

For the period 1983 through 1987, the statistical results were similar and also appeared fairly conclusive. *F*-tests did not indicate significance, and *p* values were all greater than 0.11 with the *p* value for US being 0.8365. The coefficient (*b*) values varied substantially and some were negative.

For the period 1988 through 2002, the *F*-test results for US, UP, BNSF, CSX, IC and GTW indicated significance. The coefficients were positive and *p* values were all less than 0.05. Except for KCS, NS, and SOO, the data were consistent with the hypothesis that capital expenditures were variable with annual output for this period.

To summarize, I did not expect to find a correlation between capital expenditures and output prior to 1988 because of financial (accounting and tax) distortions, but did anticipate that such a relationship might exist, roughly beginning in 1988, because of the fundamental engineering basis for such a relationship. The results (Table 3.1) were consistent with this.

The elasticity calculations for individual railroads were made only to establish firm-specific relationships between capital expenditures and output for the purpose of defining individual investment variability. Comparability of these results assumes relatively homogeneous prices for labor, material, and fuel. In the following sections, such differences were accounted for by using a fixed effects model in which dummy variables were used for each railroad and dummy coefficients absorb these individual differences. (Sections 4.10.1, Model Form, and 4.10.2, Error Components, provide additional discussion of these issues.)

3.6 Influence of Free Cash Flow and Net Income

Previous studies have established a significant role of cash flow as a determinant of investment behavior depending on the degree of financial constraints faced by the firm. Chapman (1996) found that where firms have greater financial constraints, free cash flow plays a larger role in investment decisions. Free cash flow is cash generated by operating activities minus cash used in investing activities, and is an important measure of the financial health of the firm and one measure of a firm’s value. Additionally, for railroads, infrastructure investment can be expected to be closely linked to free cash flow as these types of investments are difficult to recover. Because a large portion (close to 50%) of infrastructure cost is for installation (labor and equipment use that cannot be recovered) and therefore not fungible, internal cash generation is preferable (or less costly) to debt for financing such projects.

In this analysis, a panel of railroad data was used and Model 3.1 was modified to include dummy variables for each railroad (Model 3.1a). Statistical comparison of this model (Model 3.1a) to one including an FCF variable indicated that FCF was statistically significant in combination with output, and the estimated coefficient was negative. Although FCF may appropriately be considered as a factor in the estimation of capital expenditures, it could not be considered completely independent with respect to annual investment. (Statistical details are shown in the appendix.)

Capital expenditures are related to net income for the same reasons as free cash flow. Statistical comparison of Model 3.1a to one including a NI variable indicated that NI was not useful in the estimation of annual capital expenditures in combination with output (at a 95% confidence level).

A natural extension of the previous two tests was that FCF and NI variables should be included in combination with an output variable to explain variation in capital expenditures. Statistical comparison of Model 3.1a to one including both FCF and NI variables indicated that these were useful in combination with output, although correlation between output, free cash flow and net income was evident. The estimated FCF coefficient was negative, the NI coefficient was positive, and both were significant with p values of 0.0018 and 0.0159 respectively.

3.7 Lag and Causality Analysis: Capital Expenditures and Output

An important issue in this type of analysis is clarification of lag effects, including both the length of the effect and magnitude and sign of lag variable coefficients. My lag specification tests used six annual periods to determine which lags were significant.

Numerical subscripts on the variables indicate the lag period relative to the base year (t). Specifically, a subscript (t) represents the base year, (-1) represents a lag of one year, (-2) represents a lag of two years, up to (-5) which represents a lag of five years. If RI_t is capital expenditure in 2002, then RI_{-5} is capital expenditure in 1997; if RI_t is capital expenditure in 1997, then RI_{-5} is capital expenditure in 1992. Similarly, if $TGTM_t$ is gross ton miles in 2002, then $TGTM_{-5}$ is gross ton miles in 1997; if $TGTM_t$ is gross ton miles in 1997, then $TGTM_{-5}$ is gross ton miles in 1992.

OLS estimates were made in both directions with capital expenditure lags on output and output lags on capital expenditure using the models shown below:

Model 3.1a: $RI_t = TGTM_t + firm + \varepsilon$

Model 3.2: $RI_t = TGTM_t + TGTM_{-1} + TGTM_{-2} + TGTM_{-3} + TGTM_{-4} + TGTM_{-5} + firm + \varepsilon$

Model 3.3: $TGTM_t = RI_t + RI_{-1} + RI_{-2} + RI_{-3} + RI_{-4} + RI_{-5} + firm + \varepsilon$

where:

RI_t: RI_{-5} = Road Capital Expenditures (000s) years t through t-5

$TGTM_t$: $TGTM_{-5}$ = Gross Ton Miles (000s) in years t through t-5

The results (Table 3.2) indicated that gross ton mile lags did not influence current capital expenditures, in other words, that past output did not affect current capital expenditures.

Table 3.2: Lag Influence of Gross Ton Miles in predicting Road Capital Expenditures

Model 3.2		Model 3.1a	
$RI_t = TGTM_t + TGTM_{-1} + TGTM_{-2} + TGTM_{-3} + TGTM_{-4} + TGTM_{-5} + firm$		$RI_t = TGTM_t + firm$	
Regression Statistics		**Regression Statistics**	
Multiple R	0.973	Multiple R	0.971
R Square	0.946	R Square	0.943
Adjusted R Square	0.930	Adjusted R Square	0.929
Standard Error	126,627	Standard Error	127,314
Observations	118	Observations	118

ANOVA

	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	14	2.91E+13	2.08E+12	130.06	Regression	9	2.91E+13	3.23E+12	199.47
Residual	104	1.66E+12	1.60E+10		Residual	109	1.76E+12	1.62E+10	
Total	118	3.08E+13			Total	118	3.08E+13		

Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
$TGTM_t$	0.0020	0.001	3.406	**0.001**	$TGTM_t$	0.0015	0.000	10.418	**0.000**
$TGTM_{-1}$	0.0001	0.001	0.078	0.938	$TGTM_{-1}$				
$TGTM_{-2}$	-0.0016	0.001	-1.589	0.115	$TGTM_{-2}$				
$TGTM_{-3}$	0.0011	0.001	1.117	0.267	$TGTM_{-3}$				
$TGTM_{-4}$	0.0003	0.001	0.309	0.758	$TGTM_{-4}$				
$TGTM_{-5}$	-0.0004	0.001	-0.541	0.590	$TGTM_{-5}$				
UP	-35,797	149,355	-0.240	0.811	UP	-27,308	130,950	-0.209	0.835
BNSF	-27,673	133,587	-0.207	0.836	BNSF	-19,194	118,095	-0.163	0.871
CSX	17,573	71,903	0.244	0.807	CSX	17,722	63,168	0.281	0.780
NS	102,361	55,862	1.832	0.070	NS	101,734	51,982	1.957	0.053
KCS	17,495	33,160	0.528	0.599	KCS	18,002	33,225	0.542	0.589
IC	8,703	34,993	0.249	0.804	IC	9,574	34,566	0.277	0.782
SOO	2,422	33,679	0.072	0.943	SOO	2,832	33,475	0.085	0.933
GTW	-2,004	33,986	-0.059	0.953	GTW	-1,496	34,144	-0.044	0.965

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
1.29649	118	5	0.56326	0.270087	Lags do not inform the model

The results of the second test (Table 3.3) indicated that significant lag effects of capital expenditures on output were limited to three periods (i.e., RI_t, RI_{-1}, and RI_{-2}) with the most significant variable being RI_{-1}. The sign and magnitude of significant lag

Table 3.3: Lag Influence of Road Capital Expenditures in predicting Gross Ton Miles

Model 3.3		Model 3.1a	
$TGTM_t = RI_t + RI_{-1} + RI_{-2} + RI_{-3} + RI_{-4} + RI_{-5} + firm$		$TGTM_t = RI_t + firm$	
Regression Statistics		Regression Statistics	
Multiple R	0.990	Multiple R	0.985
R Square	0.980	R Square	0.971
Adjusted R Square	0.967	Adjusted R Square	0.960
Standard Error	5.08E+07	Standard Error	5.90E+07
Observations	118	Observations	118

ANOVA	*df*	*SS*	*MS*	*F*	ANOVA	*df*	*SS*	*MS*	*F*
Regression	14	1.28E+19	9.17E+17	355.33	Regression	9	1.27E+19	1.41E+18	406.87
Residual	104	2.68E+17	2.58E+15		Residual	109	3.79E+17	3.48E+15	
Total	118	1.31E+19			Total	118	1.31E+19		

Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
RI_t	125.6	42.4	2.961	**0.004**	RI_t	327.1	31.4	10.418	**0.000**
RI_{-1}	172.0	44.7	3.851	**0.000**	RI_{-1}				
RI_{-2}	128.5	45.9	2.797	**0.006**	RI_{-2}				
RI_{-3}	1.1	42.7	0.027	0.979	RI_{-3}				
RI_{-4}	-28.9	39.0	-0.740	0.461	RI_{-4}				
RI_{-5}	15.9	36.1	0.439	0.661	RI_{-5}				
UP	3.4E+08	5.6E+07	6.019	**0.000**	UP	4.4E+08	4.3E+07	10.210	**0.000**
BNSF	3.1E+08	4.9E+07	6.381	**0.000**	BNSF	3.9E+08	4.0E+07	9.975	**0.000**
CSX	1.3E+08	2.7E+07	4.870	**0.000**	CSX	1.8E+08	2.4E+07	7.536	**0.000**
NS	6.0E+07	2.6E+07	2.348	**0.021**	NS	1.0E+08	2.2E+07	4.677	**0.000**
KCS	5.5E+06	1.3E+07	0.409	0.684	KCS	1.1E+07	1.5E+07	0.692	0.490
IC	1.1E+07	1.4E+07	0.788	0.432	IC	1.8E+07	1.6E+07	1.111	0.269
SOO	1.5E+07	1.3E+07	1.134	0.259	SOO	2.1E+07	1.5E+07	1.348	0.181
GTW	8.3E+06	1.4E+07	0.612	0.542	GTW	1.0E+07	1.6E+07	0.646	0.520

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
8.97242	118	5	3.89811	0.0000003	Lags inform the model

coefficients were all positive, with the largest coefficient on the current period variable (RI_t). The initial interpretation was that next year's capital spending plan drives current output, an illogical relationship since transportation demand is derived principally from general economic conditions. Because railroads are common carriers, they cannot determine their own output in the short run, and output is logically an exogenous variable in the short-run. This interpretation is somewhat ambiguous, however, as long-run declines in capital expenditures will eventually constrict capacity and output of the rail network.

A Granger causality test was conducted comparing the models shown below to establish if GTM causes RI and/or if RI causes GTM. In this instance a variable with the subscript (+1) indicates the opposite of a one-year lag. For example, if RI_t is capital expenditure in 2000, then RI_{+1} is capital expenditure in 2001; if RI_t is capital expenditure in 2001, then $RI_{+1}$is capital expenditure in 2002. The same logic was applied to the other variables.

Model 3.4: $RI_t = RI_{-1} + RI_{-2} + RI_{-3} + TGTM_{+1} + TGTM_t + TGTM_{-1} + TGTM_{-2} + \text{firm} + \varepsilon$

Model 3.5: $RI_t = RI_{-1} + RI_{-2} + RI_{-3} + \text{firm} + \varepsilon$

where:

$RI_t : RI_{-3}$	= Road Capital Expenditures (000s) in years t through t-3
$TGTM_{+1}$	= Gross Ton Miles (000s) in year t+1
$TGTM_t : TGTM_{-2}$	= Gross Ton Miles (000s) years t through t-2

Results (Table 3.4) indicated that TGTM Granger caused RI_t and the hypothesis that output causes road capital expenditures was accepted.

Table 3.4**:** Causality Test: Influence of Gross Ton Miles on Capital Expenditures

Model 3.4		Model 3.5	
$RI_t = RI_{-1} + RI_{-2} + RI_{-3} + TGTM_{+1} + TGTM_t + TGTM_{-1} + TGTM_{-2} + \text{firm}$		$RI_t = RI_{-1} + RI_{-2} + RI_{-3} + \text{firm}$	
Regression Statistics		Regression Statistics	
Multiple R	0.982	Multiple R	0.976
R Square	0.964	R Square	0.953
Adjusted R Square	0.948	Adjusted R Square	0.938
Standard Error	1.03E+05	Standard Error	1.16E+05
Observations	110	Observations	110

Table 3.4 (*continued*)

Model 3.4					Model 3.5				
$RI_t = RI_{-1} + RI_{-2} + RI_{-3} + TGTM_{+1} + TGTM_t + TGTM_{-1} + TGTM_{-2} + firm$					$RI_t = RI_{-1} + RI_{-2} + RI_{-3} + firm$				

ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	15	2.69E+13	1.79E+12	167.50	Regression	11	2.66E+13	2.41E+12	180.93
Residual	95	1.02E+12	1.07E+10		Residual	99	1.32E+12	1.33E+10	
Total	110	2.79E+13			Total	110	2.79E+13		

Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
RI_{-1}	0.286	0.096	2.982	**0.004**	RI_{-1}	0.531	0.086	6.146	**0.000**
RI_{-2}	0.436	0.103	4.227	**0.000**	RI_{-2}	0.467	0.104	4.477	**0.000**
RI_{-3}	-0.171	0.080	-2.139	**0.035**	RI_{-3}	-0.251	0.085	-2.961	**0.004**
$TGTM_{+1}$	0.002	0.000	4.569	**0.000**	$TGTM_{+1}$				
$TGTM_t$	-0.001	0.001	-1.935	0.056	$TGTM_t$				
$TGTM_{-1}$	0.000	0.001	0.389	0.698	$TGTM_{-1}$				
$TGTM_{-2}$	-0.001	0.001	-0.937	0.351	$TGTM_{-2}$				
UP	11,193	127,952	0.087	0.930	UP	339,448	100,205	3.388	**0.001**
BNSF	28,104	115,330	0.244	0.808	BNSF	327,280	88,200	3.711	**0.000**
CSX	43,638	59,844	0.729	0.468	CSX	177,518	51,511	3.446	**0.001**
NS	47,731	50,227	0.950	0.344	NS	137,399	50,916	2.699	**0.008**
KCS	11,206	28,107	0.399	0.691	KCS	20,567	31,269	0.658	0.512
IC	6,768	29,390	0.230	0.818	IC	18,791	32,556	0.577	0.565
SOO	6,475	28,393	0.228	0.820	SOO	18,303	31,300	0.585	0.560
GTW	1,031	28,813	0.036	0.972	GTW	9,868	32,089	0.308	0.759

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
7.44115	110	4	3.01567	0.000024	TGTM Granger causes RI

To further define the relationship between road investment and output, and to look for other important variables that might cause road investment, additional tests were conducted.

A causality test was conducted comparing the models shown below:

Model 3.6: $TGTM_t = TGTM_{-1} + TGTM_{-2} + TGTM_{-3} + RI_t + RI_{-1} + RI_{-2} + RI_{-3} + firm + \varepsilon$

Model 3.7: $TGTM_t = TGTM_{-1} + TGTM_{-2} + TGTM_{-3} + firm + \varepsilon$

Results (Table 3.5) indicated that RI Granger caused $TGTM_t$. A logical explanation for these results is that demand in the near future (up to a two-year

Table 3.5**:** Causality Test: Influence of Capital Expenditures on Gross Ton Miles

Model 3.6					Model 3.7				
$TGTM_t = TGTM_{-1} + TGTM_{-2} + TGTM_{-3} + RI_t + RI_{-1} + RI_{-2} + RI_{-3} +$ firm					$TGTM_t = TGTM_{-1} + TGTM_{-2} + TGTM_{-3} +$ firm				
Regression Statistics					Regression Statistics				
Multiple R		0.999			Multiple R		0.998		
R Square		0.997			R Square		0.996		
Adjusted R Square		0.987			Adjusted R Square		0.987		
Standard Error		1.90E+07			Standard Error		2.12E+07		
Observations		118			Observations		118		
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	15	1.31E+19	8.71E+17	2418.44	Regression	11	1.31E+19	1.19E+18	2653.11
Residual	103	3.71E+16	3.60E+14		Residual	107	4.79E+16	4.47E+14	
Total	118	1.31E+19			Total	118	1.31E+19		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
$TGTM_{-1}$	1.014	0.096	10.599	**0.000**	$TGTM_{-1}$	1.187	0.095	12.466	**0.000**
$TGTM_{-2}$	-0.387	0.134	-2.893	**0.005**	$TGTM_{-2}$	-0.489	0.143	-3.422	**0.001**
$TGTM_{-3}$	0.276	0.099	2.798	**0.006**	$TGTM_{-3}$	0.302	0.104	2.899	**0.005**
RI_t	16.554	16.936	0.977	0.331	RI_t				
RI_{-1}	62.357	17.578	3.547	**0.001**	RI_{-1}				
RI_{-2}	12.365	17.491	0.707	0.481	RI_{-2}				
RI_{-3}	-36.648	13.835	-2.649	**0.009**	RI_{-3}				
UP	4.65E+07	2.08E+07	2.236	**0.028**	UP	3.41E+07	2.24E+07	1.525	0.130
BNSF	4.08E+07	1.88E+07	2.174	**0.032**	BNSF	2.82E+07	2.02E+07	1.395	0.166
CSX	1.57E+07	9.97E+06	1.574	0.119	CSX	1.17E+07	1.08E+07	1.085	0.280
NS	1.18E+07	8.56E+06	1.377	0.171	NS	1.31E+07	8.67E+06	1.511	0.134
KCS	4.03E+05	4.98E+06	0.081	0.936	KCS	1.03E+06	5.53E+06	0.186	0.852
IC	7.52E+05	5.20E+06	0.145	0.885	IC	7.29E+05	5.77E+06	0.126	0.900
SOO	5.52E+05	5.02E+06	0.110	0.913	SOO	1.63E+05	5.59E+06	0.029	0.977
GTW	1.31E+06	5.09E+06	0.257	0.798	GTW	1.11E+06	5.67E+06	0.196	0.845

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
7.76373	118	4	3.15609	0.000014	RI Granger causes TGTM

horizon) was anticipated and included in railroad investment plans. This would suggest that overall infrastructure capital spending budgets were determined by railroad finance managers on the basis of anticipated near term demand for railroad services. Although engineering departments may allocate capital funds partly on the basis of past wear and tear, it appears that the overall capital budget was determined (or caused) by anticipated output. Granger causality tests using balanced panel data, shown in the appendix, confirmed the inter-relationship (or "feedback") between current capital expenditures and current and future output.

3.8 Lag and Causality Analysis: Capital Expenditures, Net Income, and Free Cash Flow

Additional tests were conducted to further define potential causes of capital expenditures to support or question earlier results that found that output causes road capital expenditures.

Free Cash Flow and Capital Expenditure Lag Specification: Similar to the previous analysis, lag specification tests used six annual periods to define significant lag periods. Similar to previous tests, variable subscripts indicate either the base year (t) or the lag year (-1, -2, -3, -4, or -5). Regression of free cash flow lags on capital expenditures, similar in construction to output and capex regressions described above, indicated that FCF_t, FCF_{-1}, FCF_{-2}, and FCF_{-4} variables were significant (*p* values of 0.000, 0.002, 0.010, and 0.012, respectively). The coefficient of every FCF variable was negative for the six periods included in the analysis. The correlation was strong (adjusted $R^2 = 0.91$) and *F*-tests indicated significant results. Adjusted correlation coefficients (adjusted R^2) were used because of different degrees of freedom inherent in the model comparisons used in this analysis.

Regression of RI lags on FCF indicated that RI_t and RI_{-4} were significant (*p* values of 0.004 and 0.014, respectively). Coefficient signs were mixed and overall correlation was weak (adjusted $R^2 = 0.32$).

Free Cash Flow and Capital Expenditure Causality Analysis: Granger causality test results were similar to lag specification test results. These indicated influence of FCF on RI (*p* value = 0.0062) with only FCF_t being significant. All FCF variables had negative coefficients. Correlation was strong (adjusted $R^2 = 0.94$) and *F*-tests indicated significant results. Causality tests also indicated the influence of capital expenditures on

FCF (p = 0.0000) with RI_t and RI_{-2} being significant (p values of 0.000 and 0.011, respectively), but correlation was weak (adjusted R^2 = 0.3).

In summary, there was evidence of feedback from FCF to RI, but RI was a more reliable determinant of FCF than the other way around. Additionally, FCF coefficients were consistently negative.

Net Income and Capital Expenditure Lag Specification: Regression of net income lags on capital expenditures, similar in construction to the tests described above, indicated that NI_t and NI_{-2} were significant (p values of 0.000 and 0.010, respectively). The coefficient of every NI variable was positive for each of the six periods. Correlation was strong (adjusted R^2 = 0.92) and F-tests indicated a significant regression estimate. Regression of capital expenditure lags on net income indicated that only RI_t was significant (p = 0.009). Coefficient signs were generally positive and the correlation was moderate (adjusted R^2 = 0.78). RI lags had influence on NI but were not individually significant (p values greater than 0.05).

Net Income and Capital Expenditure Causality Analysis: Causality test results indicated influence of NI on RI (p = 0.0018) with NI_t being the most significant variable. All but one of the coefficients were positive. Correlation was strong (adjusted R^2 = 0.94) and F-tests indicated a significant regression estimate. Causality tests also indicated influence of capital expenditures on net income (p = 0.0000) with only RI_t having significance (p = 0.025). Correlation was moderate (adjusted R^2 = 0.79).

In summary, there was evidence of feedback from NI to RI, but RI was a more reliable determinant of NI than the other way around. Lag effects were weak and NI coefficients were generally positive.

Net Income and Free Cash Flow Lag Specification: A final test was used to estimate lag effects of NI and FCF on RI, with output included as an independent variable. Two lag periods were included for NI and FCF variables (NI_{-1}, NI_{-2}, FCF_{-1}, and FCF_{-2}). The results indicated that, in this combination, lags for net income and cash flow were not significant in the estimation of capital expenditures, while NI_t, FCF_t, and

$TGTM_t$ were all significant. In other words, in this combination, lags for NI and FCF did not improve the model's ability to estimate RI_t. Additionally, the estimated coefficient for FCF_t was negative and the estimated coefficient for NI_t was positive.

In summary, the results of these tests did not cause me to question the previous finding that road investment was caused by gross ton miles. RI was a more reliable determinant of FCF and NI than the other way around, thus gross ton miles remained the primary causal determinant of road capital expenditures.

3.9 Estimation of Causality using Vector Auto Regression

Variables tested included TGTM, NI, FCF and RI for the eight (8) U.S. railroads for the period 1987 through 2002. Data for the year 1987 were added to the previous analysis to permit a sufficient number of lags to estimate causality probability. Statistical Analysis Software (SAS) Version 8 software was used for the analysis (SAS 2004). The VAR method used was a Granger Causality Wald Test and significance was tested using chi-square tests. All tests were conducted with a maximum lag of 3 years. The resulting values are probabilities that the causal relationship is not present. For example, a result of 0.05 is the probability that the causal relationship does not exist, in other words, a 0.95 probability that the causal relationship is present.

The first column of Table 3.6 lists the dependent variable(s) and the second column lists the independent variable(s). Tests are presented in pairs of rows, with the dependent and independent variable(s) being swapped in each pair. Probabilities of 0.05 or less are highlighted in bold.

The first two test pairs (1 & 2) included RI and TGTM and the results indicated that TGTM causes RI for US and at UP, CSX, SOO and GTW, and RI causes TGTM at BNSF and NS. A second pair of variables was tested using RI and $TGTM_{+1}$, where $TGTM_{+1}$ is thousand gross ton miles in period t+1. The results indicated that $TGTM_{+1}$ causes RI at UP, BNSF, and NS. Together, these results suggest that current capital spending is dependent on current output for US and at UP, CSX, SOO and GTW, and that current capital spending is dependent on next year's output at UP, BNSF and NS.

Table 3.6: Results of Granger Wald Tests using VAR

Granger Causality Wald Test Class I Railroad Data 1987-2002

Test Pair	Dependent Variable	Independent Variable		Large Class I Railroads				Small Class I Railroads			
			US	UP	BNSF	CSX	NS	KCS	IC	SOO	GTW
1	RI	TGTM	**0.020**	**0.001**	0.469	**0.026**	0.266	0.778	0.372	**0.048**	**0.000**
	TGTM	RI	0.996	0.950	**0.000**	0.444	**0.000**	0.537	0.507	0.572	0.977
2	RI	$TGTM_{+1}$	0.871	**0.025**	**0.000**	0.081	**0.036**	0.470	0.364	0.529	0.341
	$TGTM_{+1}$	RI	0.093	**0.029**	0.730	**0.000**	0.099	0.371	0.936	0.374	0.074
3	RI	FCF	0.143	0.408	0.330	0.117	**0.000**	0.586	0.748	**0.015**	0.062
	FCF	RI	**0.019**	0.077	0.089	0.444	0.564	0.183	0.948	0.764	0.821
4	RI	NI	0.827	0.315	0.376	0.266	0.490	0.181	0.491	0.219	0.424
	NI	RI	**0.034**	0.346	**0.011**	0.925	0.576	0.394	0.187	0.978	0.229
5	RI	FCF NI	0.083	0.150	0.152	**0.001**	**0.000**	**0.000**	0.146	0.424	0.443
	FCF NI	RI	**0.000**	**0.003**	**0.001**	**0.000**	**0.000**	0.306	**0.000**	0.272	**0.026**
6	TGTM	FCF NI	0.495	0.812	0.176	**0.000**	0.192	0.162	0.889	0.665	**0.000**
	FCF NI	TGTM	**0.035**	0.748	0.876	**0.000**	0.237	0.230	**0.000**	**0.000**	**0.000**
7	TGTM	NI	0.152	0.752	**0.044**	0.196	0.192	0.753	0.800	0.134	**0.000**
	NI	TGTM	0.092	0.129	0.370	0.820	0.464	0.710	0.129	**0.005**	**0.031**
8	TGTM	FCF	0.747	0.371	0.093	0.130	0.401	0.533	0.306	0.849	**0.000**
	FCF	TGTM	**0.050**	0.844	0.947	**0.018**	0.187	0.054	0.816	0.112	0.765
9	FCF	NI	0.254	0.906	0.729	0.575	0.216	**0.000**	0.322	**0.009**	0.053
	NI	FCF	0.491	0.739	0.460	0.429	0.373	0.805	0.545	0.192	0.364
10	RI	$NI_{+1}FCF_{+1}$	0.958	0.463	0.828	**0.000**	0.890	0.069	0.934	0.055	NFR
	$NI_{+1}FCF_{+1}$	RI	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	0.666	**0.000**	0.785	NFR

Note: Results indicate the probability that a causal relationship does not exist. In other words, a 0.05 result indicates a 0.95 probability that the causal relationship exists

The two railroads that did not indicate significant causality in either direction are KCS and IC.

The next two test pairs (3 & 4) included RI and FCF, and RI and NI. Significant results in either direction for either pair were few. For aggregate industry data, RI causes FCF and RI causes NI, but these relationships were not apparent for individual railroads except in three instances. In the cases of NS and SOO, cash flow may play a particularly significant role in the determination of capital spending because of financial constraints, for example high debt to equity ratios.

Because capital expenditures, cash flow and net income are closely interwoven, the next test pair (5) was selected to allow interaction of FCF and NI in combination. Results were significant (or almost significant) for most railroads in one or both causal directions. For example, for US, FCF and NI were clearly dependent on RI, but a reverse relationship was also evident even if not significant at a 95% level of confidence (chi-square value of 0.083). On balance, the primary direction of the causal relationship (independent to dependent variables) was from RI to FCF and NI with a high degree of feedback in the reverse direction.

It is understandable that net income and free cash flow would be more closely related to output than to infrastructure capital spending because output should be a primary determinant of revenue with direct effects on net income and cash flow, regardless of capital spending. Oddly, the next three test pairs (6, 7, & 8) failed to confirm this. In the few cases where a significant causal relationship was indicated, TGTM was usually the exogenous or independent variable.

The next test pair (9), with FCF and NI, indicated only a slight preference for NI as the independent variable, and was significant only for KCS and SOO. Finally, RI was tested with variables for next year's net income and cash flow (NI_{+1} and FCF_{+1}) as a corollary to TGTM in test pair 2 ($TGTM_{+1}$). The results (test pair 10) indicated that current period capital expenditures were a good predictor of next year's income and cash flow for aggregate US data and at UP, BNSF, CSX, NS, and IC.

Figure 3.5 is an illustration of the apparent statistical causal relationships for individual railroads. $TGTM_t$ and $TGTM_{+1}$ cause RIt, and RI_t causes $\{FCF_t, NI_t\}$ in most instances, with some cases of feedback from $\{FCF_t, NI_t\}$ to RI_t. $TGTM_t$ also has a direct effect on FCF and NI, but in fewer instances than does RI.

In summary, these tests appear to confirm that current and anticipated output was the primary determinant of current capital spending. Unexpectedly, capital expenditures were more useful than output in the prediction of free cash flow and net income. An interpretation is that financial decision makers based capital spending plans on output, but the amount of capital spending was tempered by other (non-output) related effects on income and cash flow. In this instance, cash flow and net income appeared dependent on

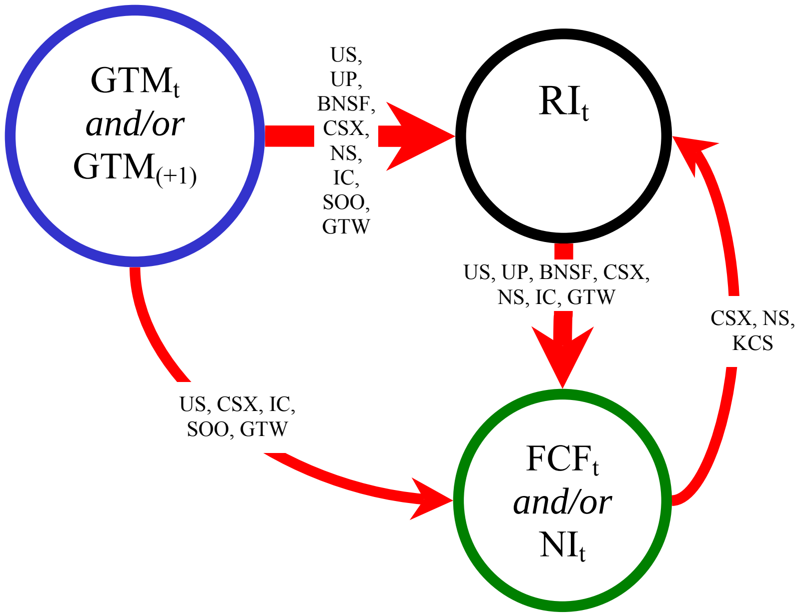

Figure 3.5: Granger Causality using VAR Class I Railroads 1987-2002

capital spending because road capital expenditures may have been a better proxy for unobservable factors determining their behavior. In other words, road capital expenditures were a better predictor of income and cash flow because they were more informed than was output.

3.10 Discussion and Conclusions

From an economic viewpoint, these results suggest that infrastructure capital expenditures are marginal costs. The degree of variability was not uniform among railroads, but in aggregate, the data were consistent with this conclusion. This conclusion was further supported by lag test results that indicated annual capital spending was related to current and future output (and not past output).

Lardner (1850, 194) made the point that prospective costs supply the basis of future tariffs, in contrast to retrospective costs that can only be used to adjust accounts after-the-fact. In commenting on cost calculations used for regulation, Alfred E. Kahn (1970, 73) stated,

> … even to the extent that depreciation does vary with use, what belongs in the marginal cost calculation is not the book cost, the writing off of investment cost historically incurred, but the amount by which this and other capital costs will be higher than they would otherwise be in the future by virtue of the incremental production in question. It is for the higher future costs or the decline in future values — not for fixed, historically sunk costs, — that the marginal production is causally responsible; it is only the future, not the past, costs that will be saved if the production is not undertaken. Notice how, at once, the traditional practices of public utility price regulation diverge from economic principles.

Wilson (1980) supported this viewpoint. "Kahn is therefore correct as long as we remember that that economic costs are prospective, not historical, and that if a shipment is to be repeated, all future costs associated with the prospective traffic need to be added. These costs not only include the variable costs of labor, fuel, etc., but also the variable capital inputs associated with the traffic."

The findings of this research contrast with regulatory cost formulae that do not include any portion of annual capital expenditures in average variable cost. The failure to include variable capital costs, per se, in variable cost calculations leads to incorrect estimates of marginal or variable cost. Although these (regulatory) formulae include a portion of depreciation and return on investment (ROI), these are not suitable surrogates for variable capital expenditures although they do serve a role in the regulatory process.

An approach used in regulatory situations is to permit regulated entities to charge a price above marginal cost that is sufficient to earn a "fair" rate of return on investment (Nicholson 2002, 518). To accomplish this, the ICC, in its development of RFA, added to its estimate of marginal cost a return on investment that was based on its estimate of the variability of investment. In doing so, the ICC (incorrectly) blended concepts of variable cost with the (correct) notion that ROI should be included in rate regulation. It (incorrectly) explained that this ROI add-on was necessary to compute "average variable cost." The ICC (1980, 35) went further in explaining the social desirability for ROI in cost estimates. “Failure to consider new investment in facilities used to service captive shippers would be inconsistent with our responsibility to encourage useful and socially desirable investment by the railroads. Movement specific investments must be *rewarded* if additional investments are to be encouraged” (emphasis added).

Depreciation may be a convenient method to even out annual fluctuation in capital expenditures, but if used in this way, it must equal total variable capital expenditures over a relatively short time horizon. Regardless of the method to smooth out annual variation, it is the level of (variable) capital spending that ultimately determines what goes into the cost formulae to account for variable investment.

To summarize, (1) the inclusion of ROI in cost formulae is appropriate for maximum rate regulation, but not minimum rate regulation; (2) the exclusion of variable capital expenditures in cost formulae results in understated variable cost estimates; and (3) ROI and depreciation are not variable costs per se, and using them as such leads to confusion.

With the development of URCS, Westbrook explained that average or intermediate run “is defined in the RAPB [Railroad Accounting Principles Board] Final Report as a ‘time period during which some but not all capacity limiting input factors may be changed.” Although inconsistent with economic theory, this mis-interpretation of variable cost may have derived from guidance given by Congress. “The House of Representatives provided guidance to the ICC in defining variable cost as follows: … it is the Committee’s intention that the Commission [ICC] apply modern cost accounting and financial analysis and that such items as administrative expenses, depreciation, interest payments, capital expenses, and other fixed costs or costs which do not vary immediately and directly as a result of the service at issue shall not be included” (U.S. DOT 1978, 120). Although Congress’s intentions were somewhat vague, it appears that it did not expressly forbid capital expenses from variable cost calculations if they could be shown to be variable with traffic on a short-run basis.

To further clarify the appropriate role of ROI in the current regulatory cost framework, I define ROI as an opportunity cost that is needed to assure a fair return when maximum rate determinations are adjudicated. Combining this with the ICC’s original cost framework, “average variable cost” would include a return on the variable portion of investment. As a result, URCS' average variable cost is then the sum of marginal cost plus "variable opportunity cost" (even though variable opportunity cost is misleading as opportunity cost is not variable, per se) as shown below.

URCS Marginal Cost
\+ <u>URCS Variable Opportunity Cost (variable ROI)</u>
URCS Average Variable Cost

The finding that capital expenditures are variable with and caused by output suggests that aggregate investment is also variable with output. The fact that annual capital expenditures substantially exceed annual depreciation expense supports this conclusion. Although this thesis does not estimate the variability of aggregate investment directly, it is logical that the variability of these two measures of investment (annual and aggregate) are similar, a deduction used by the ICC in its original cost studies. A reasonable extension suggests that return on (aggregate) investment was (and continues to be) underestimated by URCS, given that industry output was expanding during this period.

In total, average variable cost estimates made by URCS were, and continue to be, erroneous in at least two respects: First, URCS does not use variable capital expenditures in computations of marginal cost (Figure 3.6).

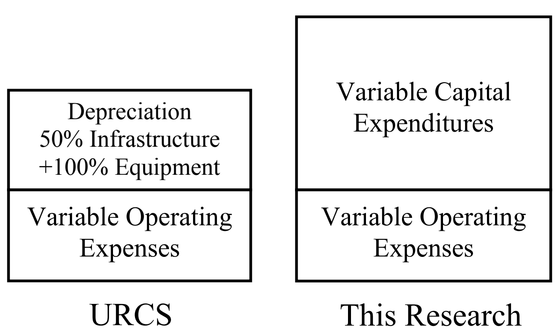

Figure 3.6: Comparison of marginal cost

URCS uses 50% of infrastructure depreciation and the computation of marginal cost is therefore erroneous in two additional respects: (a) incremental capital costs belong in the calculation, not depreciation, and (b) the ICC used only 50% of depreciation based on its 1939 assumption that 50% of aggregate investment was variable with output.

Second, in its ROI calculation, URCS uses only 50% of the (infrastructure) asset base that ultimately derives from the ICC's original assumption (of 50% investment variability). In a period in which capital expenditures were made to expand capacity and substantially exceeded depreciation costs, aggregate investment also expanded with output. As a result, within this regulatory framework, "variable ROI" should be calculated as a return on all investment that is variable with output (Figure 3.7).

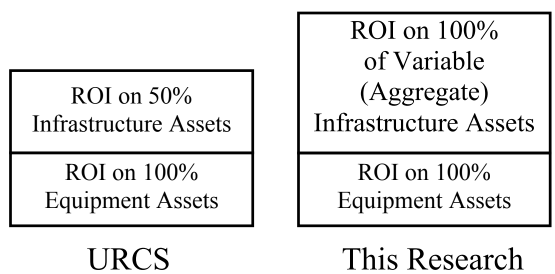

Figure 3.7: Comparison of 'variable ROI'

The above descriptions of URCS and RFA are consistent with views of experts at the STB based on personal discussions. It should also be noted that in certain types of rate litigation hearings before the STB, railroads are allowed to include capital expenditures that are made solely for the traffic at issue. These Stand-Alone-Railroad (SAR) cases are modified from the normal URCS costing methodology and costs are modified and closely tailored to fit the specific traffic under litigation.

Beyond the regulatory environment, in commercial settings, the degree to which annual capital expenditures are included in marginal cost estimates was not directly observable, but trends in free cash flow and net income provided clues that these formulae might also need revision. In an industry heavily dependent on capital expenditures, proper estimation of marginal cost is important to profitable pricing decisions.

The overall negative correlation of capital expenditures to free cash flow is problematic from a long-run investment perspective. Although declining free cash flows may occur in some rapidly growing companies, this comes from increasing requirements for working capital and investments made for long-run growth. Net working capital for railroads, however, has been falling and the largest portion of continuing investment appears related to short run growth and ongoing renewal. Since current financial theory holds that the firm value is related to the net present value of all current and future free cash flows, investment that is inversely related to free cash flow will eventually be constrained unless the long-run growth rate rises because of current investment.

The finding that capital spending is a better predictor of free cash flow and net income than output is not intuitive at first glance. Output should be a primary determinant of revenue and costs, from which free cash flow and net income are derived. However, other non-output factors affect financial performance, and it is reasonable that financial managers would consider these in their investment plans. This is consistent with views of experts in the financial industry based on personal discussions. In this manner, annual capital spending may serve as a better proxy (than output) for unobservable factors that determine free cash flow and net income.

3.11 Appendix

3.11.1 Influence of Free Cash Flow and Net Income

A statistical test was conducted comparing Model 3.1a to Model 3.8 shown below:

Model 3.1a: $RI = b\text{TGTM} + \text{firm} + \varepsilon$

Model 3.8: $RI = b\text{TGTM} + c\text{FCF} + \text{firm} + \varepsilon$

where:

RI = Road Capital Expenditures

TGTM = Thousand Gross Ton Miles

FCF = Free Cash Flow (000's 2001$s)

Table 3.7: Statistical comparison of Models 3.1a and 3.8

	Overall Model		TGTM		FCF	
Model	Adjusted R^2	F/F_c	*b*	*p*	*c*	*p*
3.1a	0.93	101.42	0.0015	4.7E-18		
3.8	0.93	99.46	0.0014	1.95E-16	-0.09	0.00739

Table 3.8: Joint Hypothesis Test of Model 3.1a and Model 3.8

F	Observations	New Parameters	F/F_c	*p*	Result
7.45409	118	1	1.89719	0.0073	Do Not Reject Model 3.8

Although comparison of the adjusted R^2 statistic did not indicate a change in correlation, *F*-test results indicated that Model 3.8 was less significant than Model 3.1a. *P* values indicated that cash flow was a significant variable. A joint hypothesis test was conducted using a standard *F*-test. The results did not allow me to reject Model 3.8 in preference to Model 3.1a. In other words, free cash flow was a useful explanatory variable in estimating road capital expenditures.

A statistical test was next conducted comparing Model 3.1a to Model 3.9 as shown below:

Model 3.1a: $RI = b\text{TGTM} + \text{firm} + \varepsilon$

Model 3.9: $RI = b\text{TGTM} + c\text{NI} + \text{firm} + \varepsilon$

where:

NI = Net Income (000's 2001$s)

Table 3.9: Statistical comparison of Models 3.1a and 3.9

	Overall Model		TGTM		NI	
Model	Adjusted R^2	F/ F_c	*b*	*p*	*c*	*p*
3.1a	0.93	101.42	0.0015	4.7E-18		
3.9	0.93	95.66	0.0014	1.40E-08	0.12	0.00729

Table 3.10: Joint Hypothesis Test of Models 3.1a and 3.9

F	Observations	New Parameters	F/F_c	*p*	Result
3.279	118	1	0.83456	0.07272	Reject Model 3.9

The adjusted R^2 statistic indicated equivalent correlation, and *F*-test results indicated that Model 3.9 was less significant than Model 3.1a. *P* values indicated that the net income variable was influential, but not as significant as the output variable. Results of a joint hypothesis test allowed me to reject Model 3.9 in preference to Model 3.1a, but only with an alpha of 0.05 ($p = 0.0727$). In other words, net income was not a useful explanatory variable in estimating road capital expenditures in combination with an output variable.

A statistical comparison was made of Model 3.1a with Model 3.10 as shown below:

Model 3.1a: $RI = b\text{TGTM} + \text{firm} + \varepsilon$

Model 3.10: $RI = b\text{TGTM} + c\text{FCF} + d\text{NI} + \text{firm} + \varepsilon$

Table 3.11: Statistical comparison of Models 3.1a and 3.10

	Overall Model		TGTM		FCF		NI	
Model	Adjusted R^2	F/F_c	*b*	*p*	*c*	*p*	*d*	*p*
3.1a	0.93	99.5	0.0014	1.95E-16	-0.093	7.39E-03		
3.10	0.94	96.9	0.0011	1.27E-06	-0.108	1.81E-03	0.159	1.59E-02

Table 3.12: Joint Hypothesis Test of Models 3.1a and 3.10

F	Observations	New Parameters	F/F_c	*p*	Result
6.00151	118	1	1.53042	0.01576	Do Not Reject Model 3.10

The adjusted R^2 statistic indicated minor improvement in correlation, and *F*-test results indicated that Model 3.10 was slightly less significant than Model 3.1a. *P* values indicated that both free cash flow and net income were influential variables, but not as significant as output. Results of a joint hypothesis test did not allow me to reject Model 3.10 in preference to Model 3.1a ($p = 0.0157$). In other words, net income in combination with free cash flow and output was a useful explanatory variable in estimating road capital expenditures.

3.11.2 Lag and Causality Analysis: Capital Expenditures, Net Income, and Free Cash Flow

A lag influence test was conducted comparing the models shown below:

Model 3.11: $FCF_t = RI_t + RI_{-1} + RI_{-2} + RI_{-3} + RI_{-4} + RI_{-5} + \text{firm} + \varepsilon$

Model 3.12: $FCF_t = RI_t + \text{firm} + \varepsilon$

where:

FCF_t = Free Cash Flow (000s) in current (t) year

$RI_t : RI_{-5}$ = Road Capital Expenditures (000s) years t through t-5

The results (Table 3.13) indicated that RI lags influenced FCF_t.

Table 3.13: Lag Influence of Road Capital Expenditures on Free Cash Flow

Model 3.11					Model 3.12				
$FCF_t = RI_t + RI_{-1} + RI_{-2} + RI_{-3} + RI_{-4} + RI_{-5} + firm$					$FCF_t = RI_t + firm$				
Regression Statistics					Regression Statistics				
Multiple R		0.640			Multiple R		0.523		
R Square		0.409			R Square		0.273		
Adjusted R Square		0.326			Adjusted R Square		0.211		
Standard Error		310,876			Standard Error		336,802		
Observations		118			Observations		118		
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	14	6.96E+12	4.97E+11	5.15	Regression	9	4.65E+12	5.16E+11	4.55
Residual	104	1.01E+13	9.66E+10		Residual	109	1.24E+13	1.13E+11	
Total	118	1.70E+13			Total	118	1.70E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
RI_t	-0.766	0.260	-2.952	**0.004**	RI_t	-0.694	0.179	-3.869	**0.000**
RI_{-1}	-0.275	0.273	-1.008	0.316	RI_{-1}				
RI_{-2}	0.487	0.281	1.731	0.086	RI_{-2}				
RI_{-3}	-0.211	0.261	-0.808	0.421	RI_{-3}				
RI_{-4}	0.599	0.239	2.508	**0.014**	RI_{-4}				
RI_{-5}	0.230	0.221	1.041	0.300	RI_{-5}				
UP	267,065	343,068	0.778	0.438	UP	1,217,689	247,726	4.915	**0.000**
BNSF	450,619	300,616	1.499	0.137	BNSF	1,246,020	225,917	5.515	**0.000**
CSX	197,179	166,945	1.181	0.240	CSX	607,508	135,546	4.482	**0.000**
NS	170,664	157,105	1.086	0.280	NS	561,192	127,684	4.395	**0.000**
KCS	15,122	82,141	0.184	0.854	KCS	59,840	87,821	0.681	0.497
IC	9,466	85,400	0.111	0.912	IC	68,471	90,961	0.753	0.453
SOO	11,687	82,029	0.142	0.887	SOO	58,520	87,831	0.666	0.507
GTW	-4,486	83,322	-0.054	0.957	GTW	9,491	90,155	0.105	0.916

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
5.01790	118	4	2.18005	0.00033	Lags inform the model

A lag influence test was next conducted comparing the models shown below:

Model 3.13: $RI_t = FCF_t + FCF_{-1} + FCF_{-2} + FCF_{-3} + FCF_{-4} + FCF_{-5} + firm + \varepsilon$

Model 3.14: $RI_t = FCF_t + firm + \varepsilon$

The results (Table 3.14) indicated that FCF lags influenced RI_t.

Table 3.14: Lag Influence of Free Cash Flow on Road Capital Expenditures

Model 3.13					Model 3.14				
$RI_t = FCF_t + FCF_{-1} + FCF_{-2} + FCF_{-3} + FCF_{-4} + FCF_{-5}$ + firm					$RI_t = FCF_t$ + firm				
Regression Statistics					Regression Statistics				
Multiple R		0.963			Multiple R		0.948		
R Square		0.927			R Square		0.900		
Adjusted R Square		0.909			Adjusted R Square		0.883		
Standard Error		146,941			Standard Error		168,651		
Observations		118			Observations		118		
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	14	2.86E+13	2.04E+12	94.68	Regression	9	2.78E+13	3.09E+12	108.46
Residual	104	2.25E+12	2.16E+10		Residual	109	3.10E+12	2.84E+10	
Total	118	3.09E+13			Total	118	3.09E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
FCF_t	-0.175	0.042	-4.181	**0.000**	FCF_t	-0.174	0.045	-3.869	**0.000**
FCF_{-1}	-0.131	0.042	-3.154	**0.002**	FCF_{-1}				
FCF_{-2}	-0.111	0.042	-2.627	**0.010**	FCF_{-2}				
FCF_{-3}	-0.040	0.042	-0.940	0.349	FCF_{-3}				
FCF_{-4}	-0.112	0.044	-2.559	**0.012**	FCF_{-4}				
FCF_{-5}	-0.106	0.053	-1.978	0.051	FCF_{-5}				
UP	1,506,944	49,540	30.419	**0.000**	UP	1,348,973	45,867	29.411	**0.000**
BNSF	1,429,472	52,681	27.135	**0.000**	BNSF	1,238,939	47,819	25.909	**0.000**
CSX	764,335	47,562	16.070	**0.000**	CSX	615,391	44,513	13.825	**0.000**
NS	672,036	43,864	15.321	**0.000**	NS	555,955	44,460	12.505	**0.000**
KCS	77,530	37,965	2.042	**0.044**	KCS	70,493	43,549	1.619	0.108
IC	87,975	39,361	2.235	**0.028**	IC	76,080	45,081	1.688	0.094
SOO	74,745	37,954	1.969	0.052	SOO	70,610	43,548	1.621	0.108
GTW	23,612	39,277	0.601	0.549	GTW	26,318	45,076	0.584	0.561

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
8.29816	118	5	3.60517	0.00000095	Lags inform the model

A Granger causality test was conducted comparing the models shown below:

Model 3.15: $RI_t = RI_{-1} + RI_{-2} + RI_{-3} + FCF_t + FCF_{-1} + FCF_{-2} + FCF_{-3} + firm + \varepsilon$

Model 3.16: $RI_t = RI_{-1} + RI_{-2} + RI_{-3} + firm + \varepsilon$

The results (Table 3.15) indicated that FCF Granger caused RI_t.

Table 3.15: Causality Test: Influence of Free Cash Flow on Capital Expenditures

Model 3.15		Model 3.16	
$RI_t = RI_{-1} + RI_{-2} + RI_{-3} + FCF_t + FCF_{-1} + FCF_{-2} + FCF_{-3} + firm$		$RI_t = RI_{-1} + RI_{-2} + RI_{-3} + firm$	
Regression Statistics		Regression Statistics	
Multiple R	0.979	Multiple R	0.976
R Square	0.958	R Square	0.952
Adjusted R Square	0.943	Adjusted R Square	0.938
Standard Error	112,231	Standard Error	117,649
Observations	118	Observations	118

ANOVA	*df*	*SS*	*MS*	*F*	ANOVA	*df*	*SS*	*MS*	*F*
Regression	15	2.96E+13	1.97E+12	156.50	Regression	11	2.94E+13	2.67E+12	193.00
Residual	103	1.30E+12	1.26E+10		Residual	107	1.48E+12	1.38E+10	
Total	118	3.09E+13			Total	118	3.09E+13		

Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
RI_{-1}	0.477	0.094	5.084	**0.000**	RI_{-1}	0.576	0.086	6.664	**0.000**
RI_{-2}	0.400	0.098	4.065	**0.000**	RI_{-2}	0.357	0.098	3.632	**0.000**
RI_{-3}	-0.104	0.085	-1.217	0.226	RI_{-3}	-0.184	0.083	-2.212	**0.029**
FCF_t	-0.119	0.033	-3.662	**0.000**	FCF_t				
FCF_{-1}	-0.012	0.034	-0.351	0.726	FCF_{-1}				
FCF_{-2}	-0.003	0.034	-0.083	0.934	FCF_{-2}				
FCF_{-3}	0.056	0.035	1.600	0.113	FCF_{-3}				
UP	338,573	124,846	2.712	**0.008**	UP	342,074	98,137	3.486	**0.001**
BNSF	355,355	115,279	3.083	**0.003**	BNSF	342,579	86,355	3.967	**0.000**
CSX	154,095	66,803	2.307	**0.023**	CSX	156,468	51,160	3.058	**0.003**
NS	136,999	61,757	2.218	**0.029**	NS	137,536	49,381	2.785	**0.006**
KCS	18,667	29,637	0.630	0.530	KCS	18,982	30,757	0.617	0.538
IC	16,773	30,839	0.544	0.588	IC	17,580	31,936	0.550	0.583
SOO	18,031	29,595	0.609	0.544	SOO	18,060	30,769	0.587	0.558
GTW	6,537	30,063	0.217	0.828	GTW	8,021	31,497	0.255	0.799

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
3.78638	118	4	1.53923	0.00621	FCF Granger causes RI

A Granger causality test was next conducted comparing the models shown below:

Model 3.17: $FCF_t = FCF_{-1} + FCF_{-2} + FCF_{-3} + RI_t + RI_{-1} + RI_{-2} + RI_{-3} + firm + \varepsilon$

Model 3.18: $FCF_t = FCF_{-1} + FCF_{-2} + FCF_{-3} + firm + \varepsilon$

Results (Table 3.16) indicated that RI Granger caused FCF_t.

Table 3.16**:** Causality Test: Influence of Capital Expenditures on Free Cash Flow

Model 3.17					Model 3.18				
$FCF_t = FCF_{-1} + FCF_{-2} + FCF_{-3} + RI_t + RI_{-1} + RI_{-2} + RI_{-3} + firm$					$FCF_t = FCF_{-1} + FCF_{-2} + FCF_{-3} + firm$				
Regression Statistics					Regression Statistics				
Multiple R			0.619		Multiple R			0.461	
R Square			0.383		R Square			0.213	
Adjusted R Square			0.290		Adjusted R Square			0.130	
Standard Error			319,183		Standard Error			353,785	
Observations			118		Observations			118	
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	15	6.52E+12	4.35E+11	4.27	Regression	11	3.62E+12	3.29E+11	2.63
Residual	103	1.05E+13	1.02E+11		Residual	107	1.34E+13	1.25E+11	
Total	118	1.70E+13			Total	118	1.70E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
FCF_{-1}	-0.038	0.097	-0.387	0.699	FCF_{-1}	0.082	0.096	0.848	0.398
FCF_{-2}	0.084	0.097	0.859	0.392	FCF_{-2}	0.092	0.097	0.946	0.346
FCF_{-3}	0.236	0.099	2.392	**0.019**	FCF_{-3}	0.173	0.099	1.740	0.085
RI_t	-0.965	0.264	-3.662	**0.000**	RI_t				
RI_{-1}	-0.268	0.297	-0.903	0.369	RI_{-1}				
RI_{-2}	0.759	0.292	2.601	**0.011**	RI_{-2}				
RI_{-3}	0.342	0.242	1.415	0.160	RI_{-3}				
UP	438,492	364,969	1.201	0.232	UP	220,608	101,754	2.168	**0.032**
BNSF	562,108	338,135	1.662	0.099	BNSF	303,973	110,217	2.758	**0.007**
CSX	212,431	193,705	1.097	0.275	CSX	109,390	100,539	1.088	0.279
NS	196,516	178,736	1.099	0.274	NS	124,219	97,337	1.276	0.205
KCS	23,581	84,418	0.279	0.781	KCS	7,522	91,372	0.082	0.935
IC	20,093	87,810	0.229	0.819	IC	12,128	94,586	0.128	0.898
SOO	22,017	84,292	0.261	0.794	SOO	9,136	91,354	0.100	0.921
GTW	-1,025	85,519	-0.012	0.990	GTW	-8,275	94,562	-0.088	0.930

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
7.39054	118	4	3.00438	0.000024	RI Granger causes FCF

A lag influence test was conducted comparing the models shown below:

Model 3.19: $NI_t = RI_t + RI_{-1} + RI_{-2} + RI_{-3} + RI_{-4} + RI_{-5} + firm + \varepsilon$

Model 3.20: $NI_t = RI_t + firm + \varepsilon$

Results (Table 3.17) indicated that RI lags influenced NI_t.

Table 3.17**:** Lag Influence of Capital Expenditures on the prediction of Net Income

Model 3.19		Model 3.20	
$NI_t = RI_t + RI_{-1} + RI_{-2} + RI_{-3} + RI_{-4} + RI_{-5} + firm$		$NI_t = RI_t + firm$	
Regression Statistics		Regression Statistics	
Multiple R	0.901	Multiple R	0.888
R Square	0.813	R Square	0.789
Adjusted R Square	0.780	Adjusted R Square	0.764
Standard Error	201,033	Standard Error	208,611
Observations	118	Observations	118

ANOVA (Model 3.19)	*df*	*SS*	*MS*	*F*	ANOVA (Model 3.20)	*df*	*SS*	*MS*	*F*
Regression	14	1.82E+13	1.30E+12	32.23	Regression	9	1.77E+13	1.97E+12	45.18
Residual	104	4.20E+12	4.04E+10		Residual	109	4.74E+12	4.35E+10	
Total	118	2.24E+13			Total	118	2.24E+13		

Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
RI_t	0.448	0.168	2.670	**0.009**	RI_t	0.840	0.111	7.563	**0.000**
RI_{-1}	0.271	0.177	1.535	0.128	RI_{-1}				
RI_{-2}	0.282	0.182	1.552	0.124	RI_{-2}				
RI_{-3}	-0.024	0.169	-0.140	0.889	RI_{-3}				
RI_{-4}	0.166	0.154	1.072	0.286	RI_{-4}				
RI_{-5}	-0.138	0.143	-0.966	0.336	RI_{-5}				
UP	-402,648	221,850	-1.815	0.072	UP	-199,919	153,438	-1.303	0.195
BNSF	-264,859	194,398	-1.362	0.176	BNSF	-106,579	139,930	-0.762	0.448
CSX	-196,812	107,957	-1.823	0.071	CSX	-110,468	83,955	-1.316	0.191
NS	147,624	101,594	1.453	0.149	NS	235,598	79,086	2.979	**0.004**
KCS	-4,650	53,118	-0.088	0.930	KCS	4,239	54,395	0.078	0.938
IC	47,623	55,225	0.862	0.390	IC	61,383	56,340	1.090	0.278
SOO	-41,430	53,045	-0.781	0.437	SOO	-30,502	54,402	-0.561	0.576
GTW	-38,029	53,882	-0.706	0.482	GTW	-34,834	55,841	-0.624	0.534

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
2.80312	118	5	1.21783	0.01983	Lags inform the model

A lag influence test was next conducted comparing the models shown below:

Model 3.21: $RI_t = NI_t + NI_{-1} + NI_{-2} + NI_{-3} + NI_{-4} + NI_{-5} + firm + \varepsilon$

Model 3.22: $RI_t = NI_t + firm + \varepsilon$

Results (Table 3.18) indicated that NI lags influenced RI_t.

Table 3.18**:** Lag Influence of Net Income on the prediction of Capital Expenditures

Model 3.21					Model 3.22				
$RI_t = NI_t + NI_{-1} + NI_{-2} + NI_{-3} + NI_{-4} + NI_{-5}$ + Firm					$RI_t = NI_t$ + firm				
Regression Statistics					Regression Statistics				
Multiple R		0.968			Multiple R		0.962		
R Square		0.938			R Square		0.925		
Adjusted R Square		0.920			Adjusted R Square		0.910		
Standard Error		135,921			Standard Error		145,654		
Observations		118			Observations		118		
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	14	2.89E+13	2.07E+12	111.91	Regression	9	2.86E+13	3.17E+12	149.54
Residual	104	1.92E+12	1.85E+10		Residual	109	2.31E+12	2.12E+10	
Total	118	3.09E+13			Total	118	3.09E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
NI_t	0.292	0.061	4.751	**0.000**	NI_t	0.410	0.054	7.563	**0.000**
NI_{-1}	0.008	0.063	0.122	0.903	NI_{-1}				
NI_{-2}	0.145	0.056	2.611	**0.010**	NI_{-2}				
NI_{-3}	0.081	0.055	1.458	0.148	NI_{-3}				
NI_{-4}	0.102	0.057	1.787	0.077	NI_{-4}				
NI_{-5}	0.012	0.061	0.203	0.840	NI_{-5}				
UP	798,657	67,676	11.801	**0.000**	UP	930,036	60,996	15.247	**0.000**
BNSF	654,449	69,062	9.476	**0.000**	BNSF	806,055	60,294	13.369	**0.000**
CSX	342,942	45,538	7.531	**0.000**	CSX	425,418	42,782	9.944	**0.000**
NS	120,548	59,642	2.021	**0.046**	NS	245,344	52,394	4.683	**0.000**
KCS	30,970	35,384	0.875	0.383	KCS	43,077	37,756	1.141	0.256
IC	5,549	37,170	0.149	0.882	IC	22,718	39,491	0.575	0.566
SOO	55,120	35,130	1.569	0.120	SOO	57,566	37,637	1.530	0.129
GTW	40,379	36,391	1.110	0.270	GTW	32,667	38,932	0.839	0.403

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
4.43738	118	5	1.92784	0.00097	Lags inform the model

A Granger causality test was conducted comparing the models shown below:

Model 3.23: $RI_t = RI_{-1} + RI_{-2} + RI_{-3} + NI_t + NI_{-1} + NI_{-2} + NI_{-3} + \text{firm} + \varepsilon$

Model 3.8: $RI_t = RI_{-1} + RI_{-2} + RI_{-3} + \text{firm} + \varepsilon$

Results (Table 3.19) indicated that NI Granger caused RI_t.

Table 3.19: Causality Test: Influence of Net Income on Capital Expenditures

Model 3.23					Model 3.8				
$RI_t = RI_{-1} + RI_{-2} + RI_{-3} + NI_t + NI_{-1} + NI_{-2} + NI_{-3}$ + firm					$RI_t = RI_{-1} + RI_{-2} + RI_{-3}$ + firm				
Regression Statistics					Regression Statistics				
Multiple R		0.979			Multiple R		0.976		
R Square		0.959			R Square		0.952		
Adjusted R Square		0.944			Adjusted R Square		0.938		
Standard Error		110,810			Standard Error		117,649		
Observations		118			Observations		118		
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	15	2.96E+13	1.97E+12	160.71	Regression	11	2.94E+13	2.67E+12	193.00
Residual	103	1.26E+12	1.23E+10		Residual	107	1.48E+12	1.38E+10	
Total	118	3.09E+13			Total	118	3.09E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
RI_{-1}	0.509	0.091	5.572	**0.000**	RI_{-1}	0.576	0.086	6.664	**0.000**
RI_{-2}	0.260	0.101	2.578	**0.011**	RI_{-2}	0.357	0.098	3.632	**0.000**
RI_{-3}	-0.180	0.082	-2.192	**0.031**	RI_{-3}	-0.184	0.083	-2.212	**0.029**
NI_t	0.136	0.054	2.517	**0.013**	NI_t				
NI_{-1}	-0.101	0.055	-1.833	0.070	NI_{-1}				
NI_{-2}	0.107	0.047	2.293	**0.024**	NI_{-2}				
NI_{-3}	0.055	0.048	1.159	0.249	NI_{-3}				
UP	394,140	96,720	4.075	**0.000**	UP	342,074	98,137	3.486	**0.001**
BNSF	360,847	82,769	4.360	**0.000**	BNSF	342,579	86,355	3.967	**0.000**
CSX	173,586	49,548	3.503	**0.001**	CSX	156,468	51,160	3.058	**0.003**
NS	95,753	48,104	1.991	**0.049**	NS	137,536	49,381	2.785	**0.006**
KCS	17,895	28,972	0.618	0.538	KCS	18,982	30,757	0.617	0.538
IC	9,696	30,276	0.320	0.749	IC	17,580	31,936	0.550	0.583
SOO	24,713	29,137	0.848	0.398	SOO	18,060	30,769	0.587	0.558
GTW	16,030	29,853	0.537	0.592	GTW	8,021	31,497	0.255	0.799

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
4.57440	118	4	1.85957	0.00181	NI Granger causes RI

A Granger causality test was next conducted comparing the models shown below:

Model 3.24: $NI_t = NI_{-1} + NI_{-2} + NI_{-3} + RI_t + RI_{-1} + RI_{-2} + RI_{-3} + \text{firm} + \varepsilon$

Model 3.25: $NI_t = NI_{-1} + NI_{-2} + NI_{-3} + \text{firm} + \varepsilon$

Results (Table 3.20) indicated that RI Granger caused NI_t.

Table 3.20**:** Causality Test: Influence of Capital Expenditures on Net Income

Model 3.24		Model 3.25	
$NI_t = NI_{-1} + NI_{-2} + NI_{-3} + RI_t + RI_{-1} + RI_{-2} + RI_{-3} + \text{firm}$		$NI_t = NI_{-1} + NI_{-2} + NI_{-3} + \text{firm}$	
Regression Statistics		Regression Statistics	
Multiple R	0.907	Multiple R	0.882
R Square	0.822	R Square	0.777
Adjusted R Square	0.789	Adjusted R Square	0.747
Standard Error	196,678	Standard Error	216,029
Observations	118	Observations	118

ANOVA

	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	15	1.85E+13	1.23E+12	31.80	Regression	11	1.74E+13	1.59E+12	33.98
Residual	103	3.98E+12	3.87E+10		Residual	107	4.99E+12	4.67E+10	
Total	118	2.24E+13			Total	118	2.24E+13		

Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
NI_{-1}	0.219	0.097	2.273	**0.025**	NI_{-1}	0.368	0.093	3.967	**0.000**
NI_{-2}	0.027	0.085	0.315	0.753	NI_{-2}	0.167	0.086	1.954	0.053
NI_{-3}	0.064	0.085	0.757	0.451	NI_{-3}	0.149	0.085	1.748	0.083
RI_t	0.427	0.170	2.517	**0.013**	RI_t				
RI_{-1}	0.125	0.184	0.676	0.501	RI_{-1}				
RI_{-2}	0.252	0.183	1.373	0.173	RI_{-2}				
RI_{-3}	-0.061	0.149	-0.406	0.686	RI_{-3}				
UP	-311,649	182,424	-1.708	0.091	UP	359,362	94,472	3.804	**0.000**
BNSF	-220,481	158,406	-1.392	0.167	BNSF	324,826	96,803	3.356	**0.001**
CSX	-164,228	91,617	-1.793	0.076	CSX	124,492	66,866	1.862	0.065
NS	100,088	86,446	1.158	0.250	NS	262,945	81,983	3.207	**0.002**
KCS	-6,077	51,514	-0.118	0.906	KCS	21,539	56,084	0.384	0.702
IC	33,642	53,661	0.627	0.532	IC	49,473	58,702	0.843	0.401
SOO	-30,218	51,811	-0.583	0.561	SOO	12,846	55,818	0.230	0.818
GTW	-25,152	53,002	-0.475	0.636	GTW	3,112	57,789	0.054	0.957

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
6.77590	118	4	2.75452	0.000061	RI Granger causes NI

A lag influence test was next conducted comparing the models shown below:

Model 3.26: $RI_t = NI_t + NI_{-1} + NI_{-2} + FCF_t + FCF_{-1} + FCF_{-2} + TGTM_t + \text{firm} + \varepsilon$

Model 3.6: $RI_t = NI_t + FCF_t + TGTM_t + \text{firm} + \varepsilon$

Results (Table 3.21) indicated that NI and FCF lags did not influence RI_t.

Table 3.21**:** Influence of Free Cash Flow and Net Income Lags

Model 3.26		Model 3.6	
$RI_t = NI_t + NI_{-1} + NI_{-2} + FCF_t + FCF_{-1} + FCF_{-2} + TGTM_t + \text{firm}$		$RI_t = NI_t + FCF_t + TGTM_t + \text{firm}$	
Regression Statistics		Regression Statistics	
Multiple R	0.975	Multiple R	0.974
R Square	0.951	R Square	0.949
Adjusted R Square	0.935	Adjusted R Square	0.935
Standard Error	121,314	Standard Error	120,931
Observations	118	Observations	118

ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	15	2.93E+13	1.96E+12	132.95	Regression	11	2.93E+13	2.66E+12	182.14
Residual	103	1.52E+12	1.47E+10		Residual	107	1.56E+12	1.46E+10	
Total	118	3.09E+13			Total	118	3.09E+13		

Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
NI_t	0.173	0.066	2.626	**0.010**	NI_t	0.159	0.065	2.452	**0.016**
NI_{-1}	-0.079	0.064	-1.240	0.218	NI_{-1}				
NI_{-2}	0.070	0.059	1.190	0.237	NI_{-2}				
FCF_t	-0.114	0.034	-3.316	**0.001**	FCF_t	-0.108	0.034	-3.201	**0.002**
FCF_{-1}	-0.013	0.039	-0.323	0.747	FCF_{-1}				
FCF_{-2}	-0.013	0.040	-0.319	0.751	FCF_{-2}				
$TGTM_t$	0.001	0.000	2.968	**0.004**	$TGTM_t$	0.001	0.000	5.133	**0.000**
UP	345,822	233,115	1.483	0.141	UP	267,619	150,204	1.782	0.078
BNSF	321,401	209,311	1.536	0.128	BNSF	249,062	134,712	1.849	0.067
CSX	184,351	106,349	1.733	0.086	CSX	150,818	70,710	2.133	**0.035**
NS	168,866	68,630	2.461	**0.016**	NS	143,655	52,018	2.762	**0.007**
KCS	27,705	32,114	0.863	0.390	KCS	24,832	31,614	0.785	0.434
IC	15,898	33,500	0.475	0.636	IC	11,249	32,939	0.342	0.733
SOO	23,557	33,787	0.697	0.487	SOO	19,696	32,203	0.612	0.542
GTW	9,865	33,340	0.296	0.768	GTW	8,195	32,628	0.251	0.802

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
0.86339	118	4	0.35098	0.48819	NI and FCF lags are not influential

A Granger causality test was next conducted comparing the models shown below:

Model 3.27: $RI_t = TGTM_t + TM_t + firm + \varepsilon$

Model 3.1a: $RI_t = TGTM_t + firm + \varepsilon$

where: TM_t = Track Miles of each railroad in year t

Results (Table 3.22) indicated that track miles did not influence RI_t.

Table 3.22**:** Influence of Track Miles in Model 3.1a

Model 3.27					Model 3.1a				
$RI_t = TGTM_t + TM_t + firm$					$RI_t = TGTM_t + firm$				
Regression Statistics					Regression Statistics				
Multiple R		0.971			Multiple R		0.971		
R Square		0.944			R Square		0.943		
Adjusted R Square		0.930			Adjusted R Square		0.929		
Standard Error		126,856			Standard Error		127,314		
Observations		118			Observations		118		
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	10	2.91E+13	2.91E+12	181.0	Regression	9	2.91E+13	3.23E+12	199.5
Residual	108	1.74E+12	1.61E+10		Residual	109	1.77E+12	1.62E+10	
Total	118	3.09E+13			Total	118	3.09E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
$TGTM_t$	0.0014	0.000	8.692	**0.000**	$TGTM_t$	0.0015	0.000	10.418	**0.000**
TM_t	-6.895	5.155	-1.338	0.184	TM_t				
UP	423,229	361,223	1.172	0.244	UP	-27,308	130,950	-0.209	0.835
BNSF	368,714	312,974	1.178	0.241	BNSF	-19,194	118,095	-0.163	0.871
CSX	270,850	199,438	1.358	0.177	CSX	17,722	63,168	0.281	0.780
NS	307,395	162,248	1.895	0.061	NS	101,734	51,982	1.957	0.053
KCS	43,839	38,329	1.144	0.255	KCS	18,002	33,225	0.542	0.589
IC	43,962	42,979	1.023	0.309	IC	9,574	34,566	0.277	0.782
SOO	37,499	42,241	0.888	0.377	SOO	2,832	33,475	0.085	0.933
GTW	11,892	35,463	0.335	0.738	GTW	-1,496	34,144	-0.044	0.965

Joint Hypothesis F-Test Results

F	Observations	New Parameters	F/F_c	*p*	Result
1.806	118	1	0.460	0.18161	Track Miles are not influential

4.0 Recovering Capital Expenditures in Prices

"An analysis of the past expenses of a railway may have two objects – retrospective and prospective. Considered retrospectively, its purposes can only be the adjustment of accounts, an object which has no relation to our present purpose … the basis of a future tariff."

Dionysius Lardner, 1850

"If volume promises to build up substantially over time, the likelihood and cost of the required expansion in capacity must be recognized in the computation of the price floor."

William Baumol, 1962

In Chapter 3, I found that infrastructure capital expenditures changed incrementally with railway output and therefore should be included in marginal and variable cost calculations. I also observed that regulatory cost formulae, used to evaluate the fairness of rail rates, fail to consider capital expenditures as an incremental cost. I noted that free cash flow and net income trends might provide clues about the degree to which capital expenditures were considered in commercial cost calculations and price formulation.

Railroad price analysts rely, to a large extent, on the correct calculation of marginal cost to make optimal pricing decisions for specific traffic. If the estimated marginal cost of a prospective or existing movement is understated, the movement's contribution ratio will be overstated. If the contribution ratio is overstated, a decision to reduce prices to increase traffic volume or a decision to engage in certain marginally profitable traffic could lead to unintended and unobservable economic losses to the firm. These types of losses will not depress net income — net income will increase — but the true economic consequence is destructive. Free cash flow will decrease because the additional revenue would fail to recover the additional capital investment. As a result, I can estimate the extent of such losses, *ceteris paribus,* by comparing relative trends in net income and free cash flow.

Financial theory holds that the value of a firm is the net present value of present and future free cash flows (Brigham and Houston 1999, 36). Declining free cash flow indicates that the value of the firm is also declining, except in those instances when current investments are being made to increase the long-run growth factor ("g") of future free cash flows. In such instances, capital expenditures will not be correlated with current or near term output, but with long term output. In the U.S. freight railroad industry, however, current capital expenditures are primarily related to current and near term (next year's) output, as demonstrated in the previous chapter. Because these investments are principally related to short-run growth, a downward trend in free cash flow results in a decline of the value of railroad firms. Accordingly, investors would eventually require correction through constraints on capital expenditures unless an upward movement in rates could justify future investment. In the post-deregulation environment, such constraints on capital expenditures began to appear in the railroad industry in the late 1990s (U.S. Congress House Committee 2001, 34-35; Flower 2003a; Flower 2003b; Hatch 2004).

My principal hypothesis is that railroad cost and pricing systems do not consider variable capital expenditures, per se, as a component of marginal cost. Reasons for this mis-calculation may include archaic regulatory cost formulae, the use of engineering concepts in place of appropriate economic criteria, the difficulty of assigning specific capital costs to specific traffic, a general misunderstanding of the concept of marginal cost, or some combination of these. Because commercial marginal cost formulae are not directly observable, I have developed a method to test this hypothesis using publicly available industry data.

I first integrate economic concepts of variable and fixed cost with accounting concepts of expense and investment, and define net income and free cash flow using "quasi-economic" (defined in both economic and cost accounting terms) variables. I next present a new definition of price, and estimate individual price components for recovery of variable expense, fixed expense, and economic profit. I then compare trends in net income and cash flow to estimate the price component for recovery of variable investment and variable capital expenditures. I find that less than one fourth of annual capital investment was reflected in price floor (or marginal cost) calculations.

I conducted a sensitivity analysis to determine if measurable levels of error in factors used in the calculation would lead to a different conclusion. These factors include estimates of fixed expenses, cost of capital, and standard error associated with the regression estimates of variable capital expenditures. The results of the sensitivity analysis support the conclusion that capital expenditures are largely excluded from marginal cost calculations by Class I railroads.

4.1 Integrating Economic and Financial Cost Concepts

Generally accepted accounting principles categorize firm costs as either expenses or investments. If the benefit of a cost lasts for more than one year, the cost is classified as an investment; otherwise it is expensed. In railway accounting practice, the difference is often related to a concept called "unit of property." If a maintenance activity requires a quantity of material (number of crossties, carloads of ballast, length of rail) that equals or exceeds some threshold level for the particular unit of property for that material, the cost of the material and installation is classified as a capital expenditure (or property investment, PI). Otherwise, it is charged as an ordinary maintenance expense (OE).

As an example, suppose that the unit of property for ballast is one carload. In this instance, using more than one carload of ballast will result in a charge to investment accounts whereas using less than one carload will be categorized as operating expense. Accordingly, the placement of three cars of ballast would be charged to PI, while the placement of less than one car of ballast would be charged to OE. Similarly, if the unit of property for crossties is one thousand, the replacement of a thousand crossties would be considered property investment whereas the replacement of a dozen crossties would be accounted for as ordinary maintenance expense.

Economists, on the other hand, normally classify cost with respect to its relationship to output and alternative uses. Marginal cost is the change in total costs that result from changes in output, and is normally related to a short-run time horizon. Variable costs are costs that vary with output and the time horizon may be long, medium or short. As a result, specifying "variable cost" requires defining the time horizon over which the variation occurs and long-run variable costs. Long-run variable costs include all shorter run variable costs. Short-run variable costs are marginal costs. Fixed costs do not change as the level of output changes, and also require specification of a time horizon to be meaningful.

Although it is convenient to use these terms (marginal, variable and fixed) to describe costs, it is important to recognize the difference between factors required for production (resources) and costs associated with those factors, and determine if such differences are pertinent to this study. Friedman (1976, 107-9) illustrated the difference between costs and factors: "… costs incurred on account of fixed factors do not necessarily correspond to fixed costs, and costs incurred on account of variable factors do not necessarily correspond with variable costs." For example, the firm may be committed to pay a fixed sum to the owner of a variable factor whether or not it uses any of the factor, in which case it is a fixed cost. "The distinction between fixed and variable costs will coincide with the distinction between fixed and variable factors if (1) total payments to every variable factor equal the ordinate of its supply curve times the associated quantity; (2) the horizontal sector of the supply curve of a fixed factor coincides with the horizontal axis; the contractual payment to a fixed factor is not changed by dispensing with its use entirely."

For example, if Railroad A maintains its own track, and the cost of maintenance varies directly with usage, the entire cost associated with maintaining that track is a variable cost to Railroad A. If, on the other hand, Railroad A pays a fixed fee to Railroad B for maintaining that same track, regardless of how many trains, cars, or tons Railroad A runs over that track, then the cost of that track becomes a fixed cost to Railroad A. The factors required to maintain that track are still variable with usage, but Railroad B must absorb the variation in costs caused by Railroad A's usage. However, U.S. freight railroads rarely, if ever, opt for a fixed fee arrangement, choosing either to operate on their own infrastructure, pay a variable usage fee for operating on other infrastructure (trackage rights), or pay a percentage of the maintenance costs of a jointly operated property based on usage (joint facility fees). As such, the distinction between fixed and variable *factors* and fixed and variable *cost* is not pertinent to this study.

Friedman's definition of cost also offered conceptual guidance on how accounting concepts (payments and receipts) could be integrated with economic concepts of cost (fixed and variable).

> It is convenient to define total costs of a firm as equal to – or better, identical with – the firm's total receipts. Total costs then include all payments – which may be positive or negative, actual or imputed – to all factors of production, including the entrepreneurial capacity of the owner of the firm. These total payments of factors of production can be divided, at least conceptually, into three parts:
> (1) *Unavoidable contractual costs ("fixed cost").* There may be some minimum sum that the firm is committed to pay to factors of production no matter what it does and no matter how its actions turn out.
> (2) *Avoidable contractual costs ("variable costs").* Another part of the firm's costs depend on what it does but not how its actions turn out.
> (3) *Noncontractual costs ("profits").* Finally, there are payments whose amount depends on the actual receipts of the firm; these we shall call noncontractual costs. Their amount is equal to the difference between total receipts and total contractual costs and, under our assumptions, are received by the owner of the entrepreneurial capacity. These payments are generally referred to as *profits*.

Friedman explained that some of these profits are expected and should be regarded as rent. Unexpected profits constituted pure profits. In other words, the difference between total receipts and {contractual costs + rent} is economic profit.

Other economists stated that the principal difference between accounting and economic definitions of profit is called opportunity cost (Nicholson 2002, 298-99). According to Ferguson, economic profit is accounting profit minus what could be earned in the best alternative use of time and money, otherwise known as "implicit cost" (Ferguson and Gould 1975, 181). Gwartney (1977, 97) stated that implicit costs include opportunity costs associated with the use of the equity capital of the owners. Although the terminology varies from one economist to another, the concepts of rent, opportunity cost, and implicit cost are analogous. For convenience I choose to use the term opportunity cost to explain the difference between accounting and economic profit. Furthermore, because (1) this research concerns investment (and therefore returns to investment factors) and (2) there are no other opportunity costs of consequence, the cost of capital is defined as an opportunity cost. The Association of American Railroads (AAR) (2004, 2) supported this viewpoint in statements made to the Surface Transportation Board (STB) when defining cost of capital: "The cost of capital is the minimum rate of return on investment which the providers of capital require as a condition for undertaking an investment. In essence, it is the threshold rate of return on investment that makes capital investment attractive. The cost of capital is an opportunity cost in that it recognizes what investors sacrifice by not investing their funds elsewhere. Investment funds generally flow to projects and companies where the expected returns are thought to at least equal to the expected returns available from other investment opportunities, giving consideration to the relative (or commensurate) risk of investment."

A comparison of cost accounting definitions is illustrated in Figure 4.1.

<table>
<tr><th>Cost Accounting</th><th>Milton Friedman</th><th>This Research</th></tr>
<tr><td rowspan="2">Total Receipts for Services and Products (or Revenues) minus Total Invoices</td><td>Non-contractual Costs, Economic Profit portion</td><td>Economic Profit (positive or negative)</td></tr>
<tr><td>Non-contractual Costs, Rent portion</td><td>Opportunity Cost (or Cost of Capital times Net Investment)</td></tr>
<tr><td rowspan="2">Total Payments for labor, services, and material equals total expenses plus total investment expenditures</td><td>Unavoidable Contractual Costs</td><td>Fixed Costs {Operating Expenses and Investment Expenditures}</td></tr>
<tr><td>Avoidable Contractual Costs</td><td>Variable Costs {Operating Expenses and Investment Expenditures}</td></tr>
</table>

Figure 4.1: Comparison of the cost definitions used in cost accounting, by Friedman and in this research.

4.2 Contractual Costs, Net Income and Free Cash Flow

I propose that a firm's expenses and investments, their total contractual costs using Friedman's definition, can be represented as either variable or fixed, and variable and fixed costs can come in the form of either an expense or investment. This results in four quasi-economic categories of cost: variable expense, fixed expense, variable investment, and fixed investment.

Examples of variable expense are fuel, train crew labor, and infrastructure maintenance expenses that vary directly with use. Examples of relatively fixed expenses are overhead costs for administration and property taxes.

I propose a broad definition of investment that includes all cash flows that make up free cash flow, but not net income. In the railroad industry, these include capital expenditures, working capital, deferred income taxes, depreciation, property sales or purchases, and other investments. Examples of fixed investment include capital expenditures required regardless of output, for example safety technology that does not improve capacity. Examples of variable investment include renewal capital expenditures and investments in new capacity as well as other types of investment such as working capital requirements that vary with output. Variable investment may also include deferred income taxes to the degree to which they vary with output.

The formulation of total contractual cost can then be described as equation 4.1 shown below:

$$TC = E_V + I_V + E_F + I_F \tag{4.1}$$

where:

TC = Total contractual cost

E_V = Variable expense

I_V = Variable investment

E_F = Fixed expense

I_F = Fixed investment

From a cost accounting viewpoint, net income is total revenue minus total expense, including depreciation and taxes, and excludes direct or previous investment. Net income can then be computed in quasi-economic terms as follows:

$$NI = TR - E_V - E_F \tag{4.2}$$

where:

NI = Net income

TR = Total revenues

This definition of net income (equation 4.2) is found in Horngren and Foster (1987, 48) in the treatment of costs for analysis of price and investment decisions.

Using my previous definition of investment, I propose that free cash flow can be expressed using quasi-economic variables as follows:

$$FCF = TR - E_V - I_V - E_F - I_F \tag{4.3}$$

where:

FCF = Free cash flow

Although this derivation of free cash flow (equation 4.3) is not found in the literature, it is a logical extension of the cost accountant's definition of net income (equation 4.2) using this definition of investment. I will later narrow the definition of investment to include only net capital expenditures (net cash flow from capital expenditures and depreciation).

4.3 Price Components

I propose an uncommon definition of price derived from concepts of marginal cost and producer surplus. I begin with the conventional assumption that a rational firm will not knowingly provide a service that is below its estimate of marginal cost. Using my previous definition of cost, I initially define two components of price: (1) that portion of total price for recovery of variable expense (P_{ve}) and (2) that portion of total price for recovery of variable investment (P_{vi}). According to economic theory, the sum ($P_{ve} + P_{vi}$) form the price floor (marginal cost) that will justify minimum production. This is analogous to a requirement that rates have a contribution ratio (or profitability index) equal to or greater than one (1.0).

I next consider producer surplus, defined here as price for recovery of fixed cost and for economic profit. The component of price for recovery of fixed costs is defined as P_{fc} and the component of price for economic profit is defined as P_p. In combination, I propose that total price can be defined as having four components:

$$P = P_{ve} + P_{vi} + P_{fc} + P_p \tag{4.4}$$

where:

P	=	Total price
P_{ve}	=	Price component to recover variable expense
P_{vi}	=	Price component to recover variable investment
P_{fc}	=	Price component to recover fixed cost
P_p	=	Price component for economic profit

In other words, P_{ve} is the component of total price for recovery of expenses that vary with output, such as fuel and train crews. P_{vi} is the component for recovery of investment that varies with output such as renewal programs and capacity investments such as sidings and yard expansion. P_{fc} is the component for recovery of fixed costs such as administrative overhead and property taxes. P_p is the component of total price for economic profit.

Given these definitions, I propose a method to determine how these price components are satisfied so that I can investigate and estimate P_{vi} in relation to I_V. Specifically, I want to estimate the value of *b* as shown below:

$$P_{vi} = bI_V \tag{4.5}$$

where:

b = the portion of variable investment recovered in price, 0 to 1

By definition, b cannot be less than 0 or greater than 1, because any excess (greater than 1) is allocated to recovery of fixed costs and/or economic profit, and any deficit (less than zero) is subtracted from recovery of fixed costs and/or negative economic profit.

As a whole, the U.S. freight railroad industry has earned a positive net income in every year since 1988 with the sole exception of 1991 in which there was a one-time industry-wide accounting adjustment. Because railroads have sophisticated costing systems that allocate variable expenses to specific traffic movements, I conclude that virtually all traffic was priced such that revenues were, at a minimum, equal to the variable expenses associated with the movement. By definition, P_{ve} cannot exceed E_V for any given output. As a result, I conclude that, except in rare instances, this component of price is equal to variable expense for any given traffic, as shown below:

$$P_{ve} = E_V \tag{4.6}$$

Similarly, P_{fc} cannot exceed $(E_F+I_F)/Q$ for any given output and cannot be negative. I cannot assume homogeneous prices and recognize that some traffic is priced below fully allocated costs, meaning that in aggregate, $\{P_{fc} \cdot Q\}$ is less than total fixed cost. Therefore P_{fc} is defined as follows:

$$P_{fc} = c(E_F+I_F)/Q \tag{4.7}$$

where:

c = the portion of fixed costs recovered in price, 0 to 1

Q = units of output (Gross Ton Miles)

By definition, *c* cannot be less than 0 or greater than 1, because any excess (over 1) is allocated to economic profit, and any deficit (below zero) becomes negative economic profit.

As noted previously, economic profit is the return on investment earned by railroad investors minus the opportunity cost (rent, implicit cost) of that investment. Opportunity cost is defined as the cost of capital (CoC) multiplied by total investment (Net Assets) required for production. The cost of capital is an opportunity cost in that it recognizes what investors sacrifice by not investing their funds elsewhere. Economic profits are smaller than accounting profits and can be negative if opportunity costs exceed the accounting profits earned by the business (Nicholson 2002, 298-99). The corollary with respect to this price component (P_p) is that it may also be negative if opportunity costs exceed the accounting profits of the business.

Estimates provided by the Association of American Railroads indicate that the railroad industry has consistently failed to earn its cost of capital, meaning that economic profits were negative. In other words, the industry's internal rate of return (IRR) was less than its weighted average cost of capital (WACC) or that IRR < WACC. Every year, the AAR estimates the cost of capital for railroads using a method established by the STB, and submits this calculation to the STB for their approval. A more extensive discussion of how the CoC is calculated is presented in the appendix. Using these calculations along with data on industry earnings and aggregate investment, I estimate P_p as the difference between the actual return on investment and the cost of capital, multiplied by the aggregate investment divided by output, as shown below:

$$P_p = [(\text{ROIC} - \text{CoC})\ \text{NA}]/Q \tag{4.8}$$

where:

ROIC = Return on invested capital

CoC = Cost of capital (WACC)

NA = Net assets

4.4 Combining Price Components and Quasi-Economic Formulae

Beginning with equation (4.2) and substituting {Price • Quantity} for TR, I obtain equation (4.9):

$$NI = [(P - E_V)\,Q] - E_F \tag{4.9}$$

Differentiating both sides with respect to (w.r.t.) output (Q):

$$dNI/dQ = P - E_V \tag{4.10}$$

Substituting equation (4.4):

$$dNI/dQ = P_{ve} + P_{vi} + P_{fc} + P_p - E_V \tag{4.11}$$

where all units are listed in terms of dollars per Million Gross Ton Miles (MGTM).

Equations (4.5)–(4.8) are substituted into equation (4.11) resulting in equation (4.12):

$$dNI/dQ = bI_V + c(E_F+I_F)/Q + [(ROIC - CoC)\,NA]/Q \tag{4.12}$$

The same process is performed beginning with equation (4.3) resulting in equation (4.13):

$$dFCF/dQ = (b\text{-}1)I_V + c(E_F+I_F)/Q + [(ROIC - CoC)\,NA]/Q \tag{4.13}$$

Subtracting equation (4.13) from equation (4.12) I obtain:

$$dNI/dQ - dFCF/dQ = I_V \tag{4.14}$$

Equation (4.14) indicates that variable investment (I_V) is the difference between the rate of change in net income per unit of output (dNI/dQ) and free cash flow per unit of output (dFCF/dQ). Therefore, I_V can be estimated from regression estimates of dNI/dQ and dFCF/dQ. This concept is illustrated graphically in Figure 4.2.

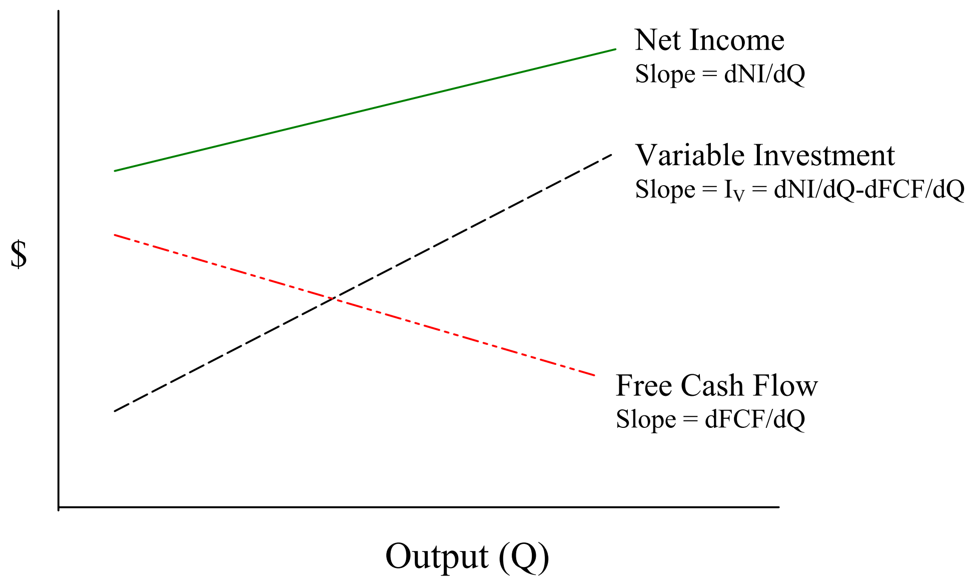

Figure 4.2: Net Income, Free Cash Flow, and Variable Investment

4.5 Methodology and Decision Criteria

Combining equations (4.14) and (4.12), an estimate of the percentage of variable investment included in marginal cost estimates was made from regressions of FCF on GTM and NI on GTM. Return on invested capital (ROIC), Net Assets (NA), output (Q) was derived from industry financial data (AAR 1978-2002a) normalized to 2001 using the Producer Price Index (PPI). Fixed cost per unit of output ($(I_F+E_F)/Q$) was estimated from AAR variability studies using industry data. The percentage of fixed costs recovered in prices (*c*) was estimated using AAR and General Accountability Office (U.S. GAO) studies.

The methodology for estimating *b* and the decision process is illustrated in Figure 4.3.

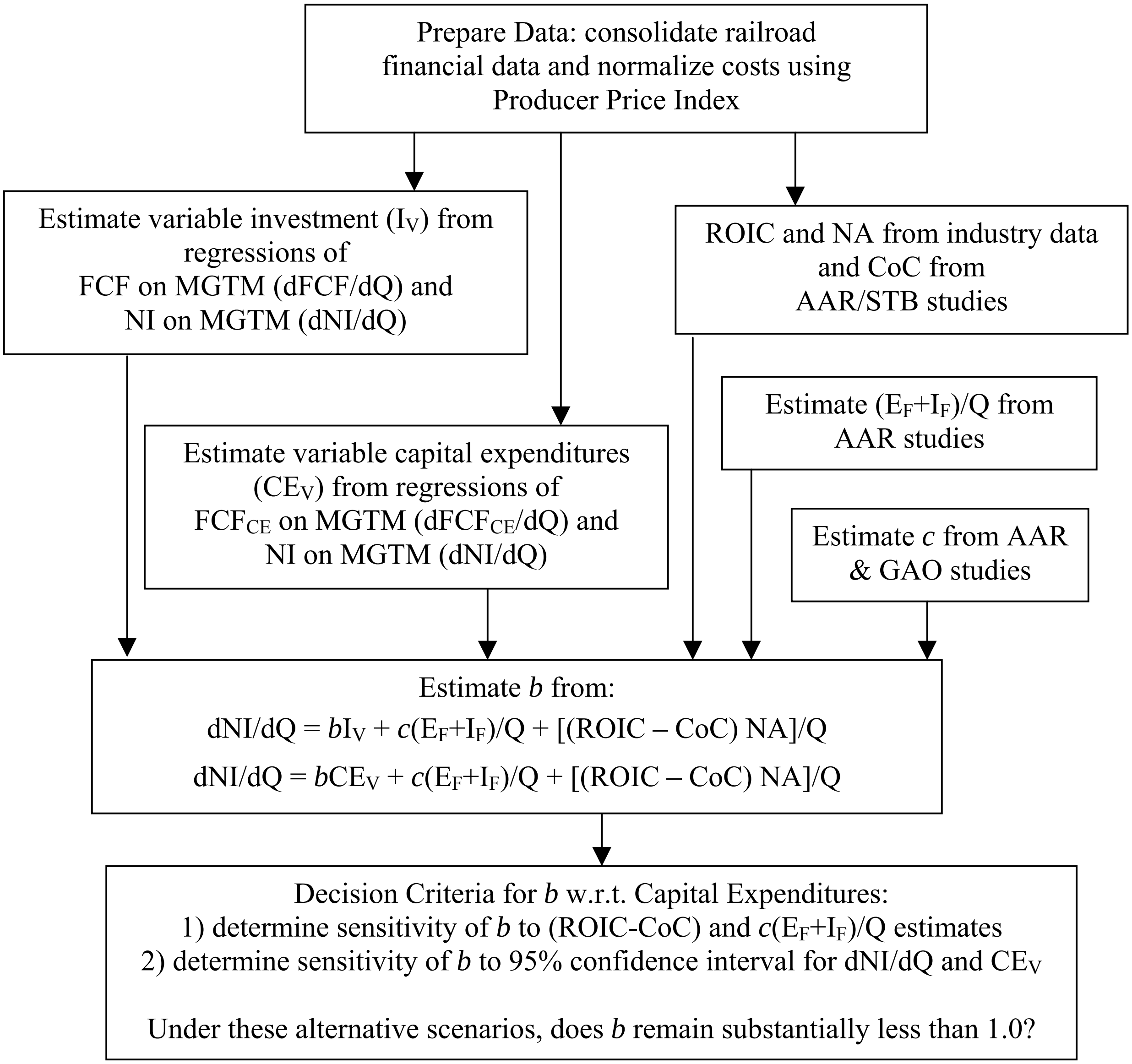

Figure 4.3: Methodology and decision analysis process

If *b* was found to be substantially less than 1.0, the hypothesis that variable capital expenditures were not sufficiently included in marginal cost estimates could not be rejected. The sensitivity of the estimate of *b* was then tested with respect to estimates of capital deficit (ROIC-CoC), the estimate of the percentage of fixed costs recovered in price ($c(E_F+I_F)/Q$) and 95% confidence intervals for dNI/dQ and CE_V. If the estimate of *b* remained substantially less than 1.0, the hypothesis could not be explained by these variations and thus could not be rejected.

4.6 Incorporating Financial Trends into Quasi-Economic Formulae

Ordinary Least Squares (OLS) regression estimates of FCF and NI with respect to Million Gross Ton Miles (MGTM) for 8 railroads were made using panel data from 8 railroad groups (representing 2001 industry configuration). Following 1998, railroads appear to have reduced the degree to which output (MGTM) influenced capital investment, in part because free cash flow had reached historical lows in 1998 and capital investments had not generated a competitive return on investment. This division of time periods with respect to investment trends was also noted in investment reports (Wolfe et al. 2004, 14).

Regression estimates are provided separately for 1988-1998 and for 1999-2002 (Table 4.1).

Table 4.1: Regression Estimate of FCF and NI with respect to GTM for 8 railroads

	Model: FCF = MGTM + firm		Model: NI = MGTM + firm		Estimate of I_V		
Period	MGTM coefficient	*p*	MGTM coefficient	*p*	dNI/dQ – dFCF/dQ	Lower 95% CI	Upper 95% CI
1988-1998	-3,973	0.0000	2,577	0.0000	6,550	5,162	7,938
1999-2002	2,231	0.1155	756	0.5709	-1,475	-4,151	1,201

The estimates of I_V and dNI/dQ (the MGTM coefficient in the NI model) calculated in Table 4.1 were substituted into equation (4.12) and yielded the following results:

1988-1998: b (\$6,550/MGTM) + $c(E_F+I_F)/Q$ + [(ROIC – CoC) NA]/Q = \$2,577/MGTM

1999-2002: b (-\$1,475/MGTM) + $c(E_F+I_F)/Q$ + [(ROIC – CoC) NA]/Q = \$756/MGTM

For these periods, I_V was \$6,550 per MGTM (1988-1998) and -\$1,475 per MGTM (1999-2002). In other words, variable investment of all types was increasing in the first period but decreasing in the second. What changed? On average, from period one to period two, net income (w.r.t output) decreased and free cash flow (w.r.t. output) increased. This means that investment of all types that varied with output changed from being a net use of funds (in 1988-1998) to being a net source of funds (1999-2002). A number of individual factors (working capital, capital expenditures, deferred income taxes, property sales, sinking funds, long-term investments, etc.) were involved in this change. These factors will be narrowed to net capital expenditures later in this section.

Estimating Fixed Cost Recovery ($c(E_F+I_F)/Q$)

Fixed cost, such as administrative overhead and property taxes, per unit of output ($(E_F+I_F)/Q$) was estimated for each period using AAR's (1991) study of railroad cost variability. The AAR estimated the overall variability at approximately 70%, equating to a 30% fixed cost ratio. Given a number of changes in the industry over this period, this percentage has probably changed, but such changes are likely modest. For example, the 1991 estimate of variable cost is remarkably close to a later estimate derived from congressional testimony in 1998. In these hearings, the AAR stated that the average Revenue to Variable Cost (R/VC) ratio must be 138 percent if all railroad costs (variable and fixed) are to be recovered (U.S. Congress House Committee 1998, 305). This implies that 28% of all costs are fixed using URCS formulae where 1.0 is defined as variable cost (0.38/1.38 = 0.28).

Using this estimate, $(E_F+I_F)/Q$ for each period was calculated as:

- 1988-1998: $(E_F+I_F)/Q$ = \$3,701 per MGTM
- 1999-2002: $(E_F+I_F)/Q$ = \$2,925 per MGTM

The decline in fixed cost per MGTM occurred for two reasons: (1) the total amount of fixed costs declined from an average of \$8.944 billion per year (1988-1998) to \$8.908 billion per year (1999-2002), and (2) total average annual output (billion gross ton miles) increased from 2,417 (1988-1998) to 3,045 (2999-2002).

I next estimated (*c*), the proportion of revenues that recover average fixed costs, using studies of railroad R/VC ratios conducted by the General Accountability Office (GAO). The GAO (2002, 25-26) stated that the proportion of all railroad revenue that came from shipments transported at rates that exceed 180 percent of variable cost stayed relatively constant at just under 30 percent (1997-2000) and 28 percent (1990-1996). I used an average of 29% meaning that traffic with rates that had an R/VC ratio *under* 180 contributed approximately 71% of total revenues, and this percentage did not vary substantially over the time horizon. This point is shown as the intersection of a vertical line (R/VC = 180) with a horizontal line (percentage of revenues = 71%) as shown in Figure 4.4.

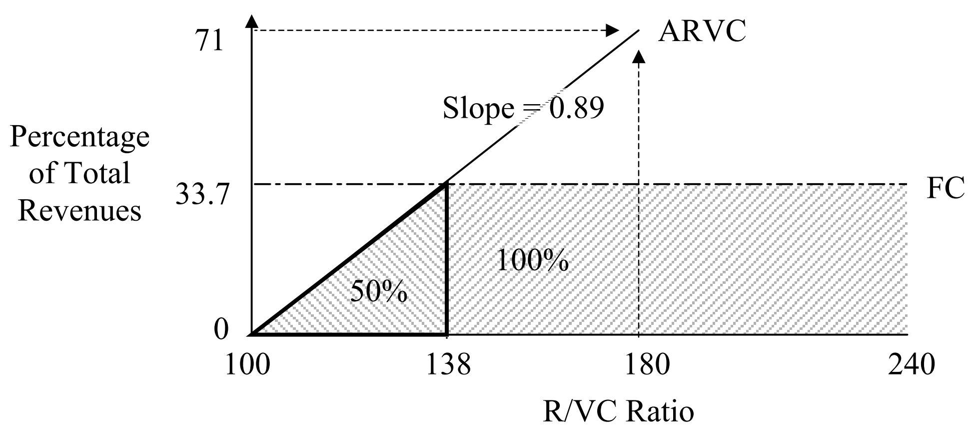

Figure 4.4: Percentage of fixed costs (FC) recovered by R/VC ratio

I next assumed that the percentage of aggregate railroad revenues (with respect to the R/VC ratio) followed a generally linear pattern between an R/VC of 100 to 180. This assumption is reasonable given the broad mix of transportation services provided by freight railroads, the wide variation of transportation service value and the use of differential pricing by railroads. It is also generally consistent with information I have seen that was derived from STB's costed waybill database. The slope of this line, which I defined as the Aggregate Revenue to R/VC Ratio (ARVC) function, was 0.8875 [={71/(180-100)}].

Since railroads recover all variable and all fixed costs at a R/VC ratio of 138 (or greater), a horizontal line was drawn that intersected the ARVC function at an R/VC of 138. This line (FC) can be thought of as representing the average fixed cost per revenue dollar. Where the ARVC function lies above this line, all fixed costs are recovered in revenues. Where it lies below (FC), less than all fixed costs are recovered. This line (FC) intersects the y-axis at 33.7 [=(0.89)(138-100)].

Traffic priced up to an R/VC of 138 recovered different percentages of their fixed expense, but the recovery rate followed the approximate geometric shape (the right triangle) shown in the area to left of {R/VC = 138}. This geometry allowed me to estimate that, in total for all traffic priced below or left of {R/VC = 138}, one-half of all fixed costs was recovered in revenues. All traffic priced above or to the right of {R/VC = 138}, recovered 100% of fixed costs.

The proportion of revenue from traffic that recovered fixed costs for each R/VC group was estimated as follows (Table 4.2):

1) Total proportion of revenues exceeding 180 = 29%,
2) Proportion of revenues between R/VC of 138 and 180 = 71% - 33.7% = 37.3%
3) Proportion of revenues below R/VC of 138 = 33.7%, of which only 50% of fixed costs are recovered, on average, by revenue received.

Table 4.2: Estimate of *c*

Traffic group with R/VC ratio:	Source or supporting calculation	Percentage of $E_F + I_F$ recovered	Percentage of total revenue that recovered $E_F + I_F$
Greater than 180	GAO Study	100%	29.0%
Between 138 and 180	71% - 33.7%	100%	37.3%
Less than 138	33.7%	50%	16.9%
Estimate of *c*			82.1%

Multiplying $(E_F+I_F)/Q$ by c, I estimated the portion of price for recovery of fixed costs as follows:

- 1988-1998: $c(E_F+I_F)/Q$ = \$3,039 per MGTM
- 1999-2002: $c(E_F+I_F)/Q$ = \$2,402 per MGTM

Estimating Economic Profit [(ROIC – CoC) NA]/Q

The AAR provided an estimate of the implied capital deficit for the railroad industry and individual Class I railroads by subtracting the actual rate of return from its estimate of the cost of capital. The calculation of railroad cost of capital is described in detail in the appendix. The average capital deficit was 5.03% (1988-1998) and 3.62% (1999-2002). In combination with equation (4.8), the estimates were:

- 1988-1998: [(ROIC – CoC) NA]/Q = -$1,019 per MGTM
- 1999-2002: [(ROIC – CoC) NA]/Q = -$765 per MGTM

In other words, the price component for economic profit improved over the past 15 years, but remained negative because railroads continued to earn a rate of return that was less than their cost of capital. The AAR uses a Discounted Cash Flow (DCF) model to estimate the cost of capital, and other models, for example, the Capital Asset Pricing Model (CAPM), may yield substantially different results. These are described in the appendix and are considered in the formulation of alternative hypotheses.

Estimating *b* with respect to Variable Investment (I_V)

Incorporating my estimates of I_V, $c(E_F+I_F)/Q$ and [(ROIC – CoC) NA]/Q into equation (4.12), I obtained the following estimates of *b*:

- 1988-1998: $b = [(2,577 - (3,039 + (-1019)))/6,550] = 0.085$
- 1999-2002: $b = [(756 - (2,402 + (1765)))/-1,475] = 0.597$

In this calculation, *b* represents the proportion of total variable investment reflected in this price component (P_{vi}). As noted earlier, this definition of investment included cash flows from a number of sources including working capital, sale or disposal of tangible assets, and depreciation and amortization offsets, deferred income taxes (DIT), sale of property, capital expenditures, sale and purchase of long-term investments. Substantial changes in these cash flows influence the estimate of I_V.

A partial cash flow statement is presented for Class I railroads (using AAR financial statistics adjusted to a 2001-year basis) in Table 4.3 to illustrate the magnitude and influence of the various sources of cash flow included in this definition. On a gross ton mile (GTM) adjusted basis, from 1988-1998 to 1999-2002:

- Net income (cash from continuing operations) fell by $125 per MGTM,
- Cash from depreciation fell by $114 per MGTM,
- Cash from deferred income taxes rose by $124 per MGTM,
- Cash from property sales fell by $235 per MGTM, and
- Cash used for capital expenditures fell by $301 per MGTM.

Table 4.3: Average Cash Flows in $'s per MGTM

AAR Report Line No. and Category	1988-1998	1999-2002	Change	
Cash Flow – Operating Activities *(sum of lines 119 through 127)*	2,523	2,273	-250	Less Source
119. Income from Continuing Operations	1,088	963	-125	Less source
120. Loss (Gain) on Sale/Disposal of Tang.	-195	-59	136	Less use
121. Depreciation and Amortization	1,200	1,085	-114	Less source
122. Increase(Decrease) in Provision for DIT	282	406	124	More source
123. Net Decrease (Increase) in Undist. Earn Aff	-37	-21	16	Less use
124. Decrease(Increase) in Accounts Receivable	2	-24	-26	Source to Use
125. Decrease(Increase) in Materials & Supplies	-18	25	43	Use to source
126. (Decrease) Incr. In Current Liabilities OTD	85	-6	-92	Source to use
127. Increase(Decrease) in Other—Net	129	-95	-224	Source to use
Cash Flow – Investing Activities *(sum of lines 131 through 136)*	-1,923	-1,833	90	Less use
131. Proceeds from Sale of Property	383	148	-235	Less source
132. Capital Expenditures	-2,116	-1,815	301	Less use
133. Proceeds from Sale/Repayment of Invest.	138	51	-87	Less source
134. Purchase Price of Long-Term Investments	-233	-45	188	Less use
135. Net Decrease(Increase) in Sinking	4	-22	-26	Source to use
136. Other Investments	-99	-150	-51	More use
Net Free Cash Flow	601	440	-161	Less source

Source: Data from AAR Analysis of Class I Railroads modified to 2001 basis using Producer Price Index

Estimating *b* with respect to Variable Capital Expenditures

To estimate *b* with respect to variable capital expenditures, that is, to isolate *b* from the effects of cash flows other than net capital expenditures, the cash flows of Net Income, Capital Expenditures, and Depreciation were added and labeled FCF_{CE} (Free Cash Flow of Capital Expenditures). In other words, FCF_{CE} is the sum of lines 119, 121, and 132 as shown in Table 4.3. Regression estimates using this modified definition of free cash flow are shown in Table 4.4. Variable Capital Expenditures (CE_V) is the variable portion of Net Capital Expenditures (Capital Expenditures minus Depreciation).

Table 4.4: Regression Estimates of FCF_{CE} and NI with respect to MGTM

	Model: FCF_{CE} = MGTM + firm		Model: NI = MGTM + firm		Estimate of CE_V		
Period	MGTM coefficient	*p*	MGTM coefficient	*p*	dNI/dQ – dFCF/dQ	Lower 95% CI	Upper 95% CI
1988-1998	-1,374	0.0030	2,577	0.0000	3,951	2,828	5,074
1999-2002	5,277	0.0002	756	0.5709	-4,521	-6,817	-2,225

A negative value for variable capital expenditures may indicate that available capacity is being consumed by increases in output and/or that track conditions are changing.

Incorporating my estimates of CE_V, $c(E_F+I_F)/Q$ and [(ROIC – CoC) NA]/Q into equation (4.12), I obtained the following estimates of *b* (w.r.t. Capital Expenditures):

- 1988-1998: $b = [\ (2{,}577 - (3{,}039 + (-1{,}019)))/3{,}951] = 0.141$
- 1999-2002: $b = [\ (756 - (2{,}402 + (-765)))/-4{,}521] = 0.195$

Autocorrelation tests indicated that OLS was the best estimator in each of the models above. Additionally, White's Approximate Estimator, as applied to the data above, indicated that the standard error for NI was less than 0.513 when heteroskedasticity is considered. These calculations are shown in the appendix.

4.7 Evaluating Results Using Sensitivity Analysis

The estimate of *b* with respect to variable capital expenditures includes three sources of error: (1) the estimate of fixed costs, (2) the estimate of cost of capital, and (3) standard error in the regression estimates of dNI/dQ, $dFCF_{CE}/dQ$, and CE_V.

<u>Sensitivity to *c* estimate</u>: In the preceding section, *c* was estimated from studies conducted by the AAR and GAO. To test the sensitivity of the results, I varied the estimates of *c* by 25% to determine if *b* remained substantially less than 1.0. The results indicated that *b* remained substantially less than 1.0 when *c* was increased or decreased by 25% (Table 4.5).

Table 4.5: Sensitivity of *b* to changes in fixed cost estimates

1988-1998

	Estimate	Reduce *c* by 25%	Increase *c* by 25%
dNI/dQ	2,577	2,577	2,577
$dFCF_{CE}/dQ$	-1,374	-1,374	-1,374
CE_V	3,951	3,951	3,951
c	82.1%	**61.6%**	**102.6%**
$(E_F+I_F)/Q$	3,701	3,701	3,701
$c(E_F+I_F)/Q$	3,039	2,279	3,799
ROIC-CoC	-5.03%	-5.03%	-5.03%
NA/Q	20,259	20,259	20,259
P_p	-1,019	-1,019	-1,019
b estimate	0.141	0.333	-0.051

1999-2002

	Estimate	Reduce $c(E_F+I_F)$ by 25%	Increase $c(E_F+I_F)$ by 25%
dNI/dQ	756	756	756
$dFCF_{CE}/dQ$	5,277	5,277	5,277
CE_V	-4,521	-4,521	-4,521
c	82.1%	**61.6%**	**102.6%**
$(E_F+I_F)/Q$	2,925	2,925	2,925
$c(E_F+I_F)/Q$	2,402	1,801	3,002
ROIC-CoC	-3.62%	-3.62%	-3.62%
NA/Q	21,142	21,142	21,142
P_p	-765	-765	-765
b estimate	0.195	0.062	0.327

Sensitivity to Cost of Capital Estimate: Alternative methods exist to estimate cost of capital and are described in the appendix. The estimate provided by the AAR uses the DCF model. An alternative to the DCF model is the CAPM method, which yields different results depending on the time period used for the estimate. To test the sensitivity of the results, I varied the differential between Return on Invested Capital and Cost of Capital (ROIC-CoC) by 50% to determine if the estimate of *b* remained substantially less than 1.0. The results of this analysis indicated that *b* remained substantially less than 1.0 when (ROIC-CoC) was increased or decreased by 50% (Table 4.6).

Table 4.6: Sensitivity of *b* to changes in ROIC-CoC estimates

1988-1998

	Estimate	Reduce ROIC-CoC differential by 50%	Increase ROIC-CoC differential by 50%
dNI/dQ	2,577	2,577	2,577
$dFCF_{CE}/dQ$	-1,374	-1,374	-1,374
CE_V	3,951	3,951	3,951
c	82.1%	82.1%	82.1%
$(E_F+I_F)/Q$	3,701	3,701	3,701
$c(E_F+I_F)/Q$	3,039	3,039	3,039
ROIC-CoC	-5.03%	**-2.52%**	**-7.55%**
NA/Q	20,259	20,259	20,259
P_p	-1,019	-510	-1,529
b estimate	0.141	0.012	0.270

1999-2002

	Estimate	Reduce ROI-CoC differential by 50%	Increase ROI-CoC differential by 50%
dNI/dQ	756	756	756
$dFCF_{CE}/dQ$	5,277	5,277	5,277
CE_V	-4,521	-4,521	-4,521
c	82.1%	82.1%	82.1%
$(E_F+I_F)/Q$	2,925	2,925	2,925
$c(E_F+I_F)/Q$	2,402	2,402	2,402
ROIC-CoC	-3.62%	**-1.81%**	**-5.43%**
NA/Q	21,142	21,142	21,142
P_p	-765	-383	-1,148
b estimate	0.195	0.279	0.110

Sensitivity to Regression Estimates of dNI/dQ and CE_V: The estimates of dNI/dQ and $dFCF_{CE}/dQ$ were used to calculate CE_V. The standard error associated with each of these estimates is therefore a source of error in the estimate of *b*. To test the sensitivity of the results, I calculated the upper and lower 95% confidence intervals for these estimates to determine if the estimate of *b* remained substantially less than 1.0. Results (Table 4.7) indicated that *b* remained substantially less than 1.0 even when regression error was considered.

Table 4.7: Sensitivity of *b* to regression error

1988-1998

	Estimate	Lower 95% CI for CE_V	Upper 95% CI for CE_V
dNI/dQ	2,577	1,879	3,275
$dFCF_{CE}/dQ$	-1,374	-2,254	-494
CE_V	3,951	**2,828**	**5,074**
c	82.1%	82.1%	82.1%
$(E_F+I_F)/Q$	3,701	3,701	3,701
$c(E_F+I_F)/Q$	3,039	3,039	3,039
ROIC-CoC	-5.03%	-5.03%	-5.03%
NA/Q	20,259	20,259	20,259
P_p	-1,019	-1,019	-1,019
b estimate	0.141	-0.050	0.247

1999-2002

	Estimate	Lower 95% CI for CE_V	Upper 95% CI for CE_V
dNI/dQ	756	499	1,013
$dFCF_{CE}/dQ$	5,277	2,996	7,558
CE_V	-4,521	**-6,817**	**-2,225**
c	82.1%	82.1%	82.1%
$(E_F+I_F)/Q$	2,925	2,925	2,925
$c(E_F+I_F)/Q$	2,402	2,402	2,402
ROIC-CoC	-3.62%	-3.62%	-3.62%
NA/Q	21,142	21,142	21,142
P_p	-765	-765	-765
b estimate	0.195	0.167	0.280

For each potential source of error (fixed cost recovery, ROIC-CoC, and regression estimate variance) the sensitivity analysis yielded results for *b* that were substantially less than 1.0, with the highest estimate being 0.333 (Table 4.5).

The difference in the estimated value of *b* for the 1988-1998 period to the 1999-2002 period, although relatively minor, raises the question of why it would change. It is possible that railroads began including a smaller share of capital expense in marginal costs although it is unlikely that they have modified their cost models in this manner in recent years. A more plausible explanation is that the variability of capital expenditures with respect to output has changed as a result of constraints on capital expenditures related to growth. Statements by the industry, the investment community, and other sources tend to confirm growing constraints on capital expenditures (U.S. Congress House Committee 2001; Flower 2003a&b; Hatch 2004).

The most likely source of variation in *b*, however, are errors associated with the OLS estimates. If this is the case, it could confirm that industry-costing techniques have not materially changed from one period to the next. This would present reasonable confirmation that the industry has not substantially changed its treatment of incremental capital expenditures with respect to marginal cost estimates consistent with earlier AAR guidance on the subject.

In summary, considering the potential sources of error, the conclusion remains that *b* is substantially less than 1.0, meaning that railroads largely excluded variable capital expenditures from marginal cost estimates, and the primary hypothesis could not be rejected.

4.8 How Economic Losses Result From Mis-estimated Marginal Costs

The concept that accurate estimates of marginal cost are essential to profit maximization may not be clear to the non-economist. Three examples of pricing decisions faced by the railroad pricing manager are presented to illustrate this concept: (1) a marginal cost traffic decision, (2) a price-volume trade-off decision, and (3) a traffic-traffic trade-off decision.

Marginal Traffic Pricing Decision. Suppose that the estimated marginal cost of a shipment is $100, but the actual marginal cost is $110 (when marginal capital expenditures are included). If a shipment is priced close to marginal cost (as many intermodal shipments appear to be), the loss incurred is fairly obvious. If the shipment is priced at $105, the economic loss is $5, as opposed to the estimated (or perceived) economic profit of $5 (Table 4.8).

Table 4.8: Marginal traffic pricing example

Traffic	Unit Price	Marginal Expense	Estimated Contribution Ratio	Estimated Earnings Contribution	Marginal Capital Expenditure	Actual Marginal Cost	FCF (economic) Contribution
Intermodal	$105	$100	1.05	$5	$10	$110	-$5

Price-Volume Trade-off Decision. Suppose again that the estimated marginal cost of a shipment is $100, but the actual marginal cost is $110. Suppose now that the initial volume is 100 shipments per month, and that the initial price is $180 per shipment. Now suppose that the shipper offers to increase the number of shipments by 20% for a price reduction of $12 per shipment (or a 6.6% price reduction). At the (incorrectly) estimated marginal cost of $100, the pricing manager will estimate the net marginal profit of the exchange at $160 per month. If the actual marginal cost is $110, however, this decision will actually result in a net monthly loss of $40 (Table 4.9).

Table 4.9: Price-volume trade-off example

Scenario		Volume	Unit Price	Marginal Cost	Marginal Profit	Net Profit	FCF Change
Initial Conditions	Estimated	100	$180	$100	$80	$8,000	
	Actual	100	$180	$110	$70	$7,000	
After Negotiation	Estimated	120	$168	$100	$68	$8,160	$160
	Actual	120	$168	$110	$58	$6,960	-$40

To illustrate graphically, a comparison is made of marginal cost curves (MC) with and without marginal capital expenditures included in Figures 4.5a and 4.5b.

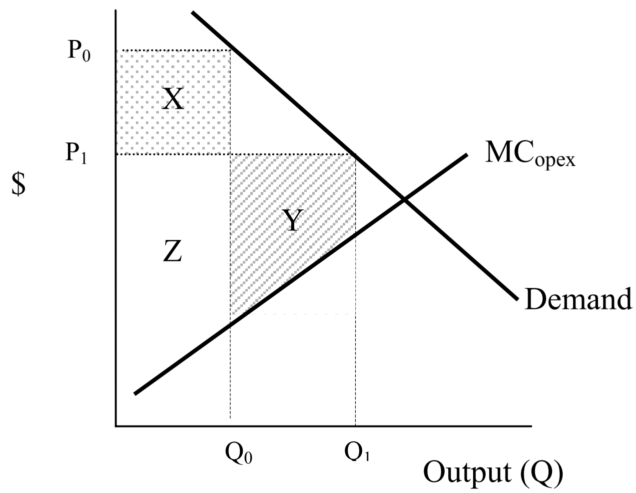

Figure 4.5a: Price volume trade-off decision without marginal capital costs

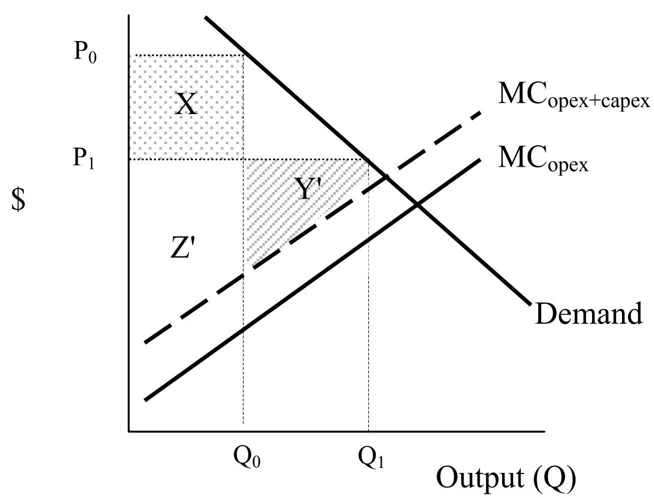

Figure 4.5b: Price volume trade-off decision with marginal capital costs

Suppose the pricing manager considers whether to reduce price from P_0 to P_1 in order to gain an increase in volume from Q_0 to Q_1. In Figure 4.5a, the price volume trade-off decision would appear to increase in producer surplus if the loss incurred by a reduction in price (area X) is more than offset from an increase in volume (area Y). As long as (Y > X), the price-volume trade-off decision is profitable. However, if marginal capital expenditures were included, the marginal cost curve shifts up (from MC_{opex} to

$MC_{opex+capex}$) and the trade-off could result in a loss of producer surplus if (Y' < X) (Figure 4.5b).

The example data provided in Table 4.9 is applied to Figures 4.6a and 4.6b.

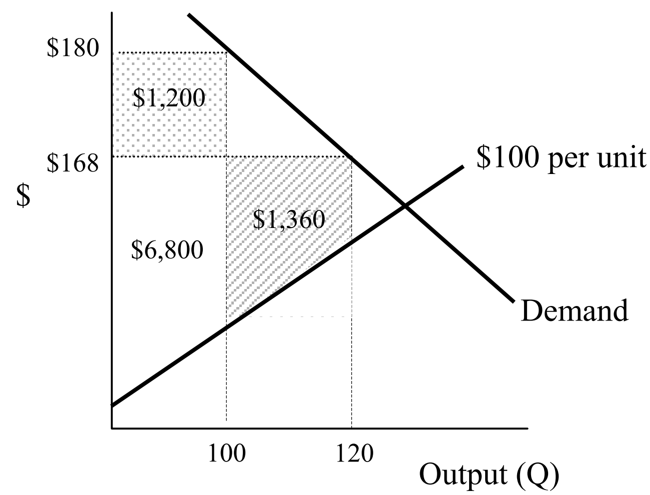

Figure 4.6a: Price volume trade-off example without marginal capital costs

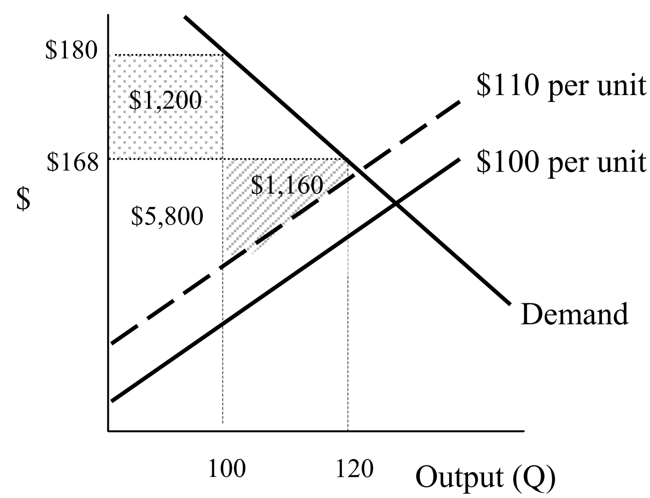

Figure 4.6b: Price volume trade-off example with marginal capital costs

The initial price (P_0) is $180 per unit and initial output (Q_0) is 100 units. The net producer surplus (areas X + Z) using a marginal cost estimate of $100 per unit is $8,000 ($1,200 + $6,800). The trade-off price (P_1) is $168 per unit and the new volume (Q_1) is 120 units (Figure 4.6a). The new producer surplus (areas Y + Z) is estimated at $8,160 ($1,360 + $6,800), a net gain of $160.

Marginal capital expenditures ($10 per unit) are now added to marginal operating expenditures for a of total of $110 per unit (Figure 4.6b). The before-trade-off producer surplus is $7,000 ($1,200 + $5,800) and the after-trade-off producer surplus is $6,960 ($1,160 + $5,800), a net loss of $40.

Traffic trade-off decision. Suppose that the railroad is congested and the marketing manager is required to make business decisions about which traffic to accept and which traffic to "de-market." In this example, excluding marginal capital expenditures in contribution ratios results in a decision to keep the coal traffic and de-market the chemical traffic. If marginal capital expenditures were included, however, the best decision would be to keep the chemical traffic and de-market the coal traffic (Table 4.10, Figure 4.7).

Table 4.10: Traffic trade-off example

Traffic	Unit Price	Marginal Expense	Estimated Contribution Ratio	Net Income	Marginal Capital Expenditure	Actual Marginal Cost	FCF (economic) Contribution
Chemical	$180	$120	1.5	$60	$10	$130	$50
Coal	$150	$80	1.9	$70	$30	$110	$40

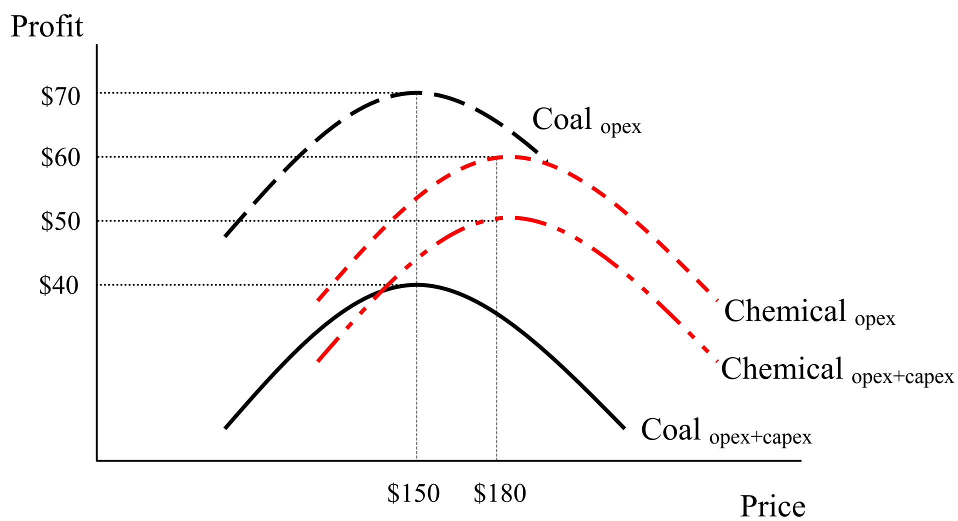

Figure 4.7: Traffic trade-off example with and without marginal capital costs

The decision to choose coal over chemical traffic appears profitable from a net income viewpoint ($70 > $60). However, when incremental capital expenditures are considered, the profitable choice based on free cash flow contribution is the chemical traffic ($50 > $40).

In each example described above (the marginal traffic decision, price-volume trade-off decision, and traffic trade-off decision), the railroad will experience growing net income concurrent with declining free cash flow as a result of not considering incremental capital expenditures. Actual economic results of each pricing decision will depend on a number of factors, and the examples provided are simply chosen to illustrate the point. That said, an examination of railroad net income and free cash flow trends (Figure 4.8) appear consistent with a hypothesis that these types of mis-calculations were not infrequent.

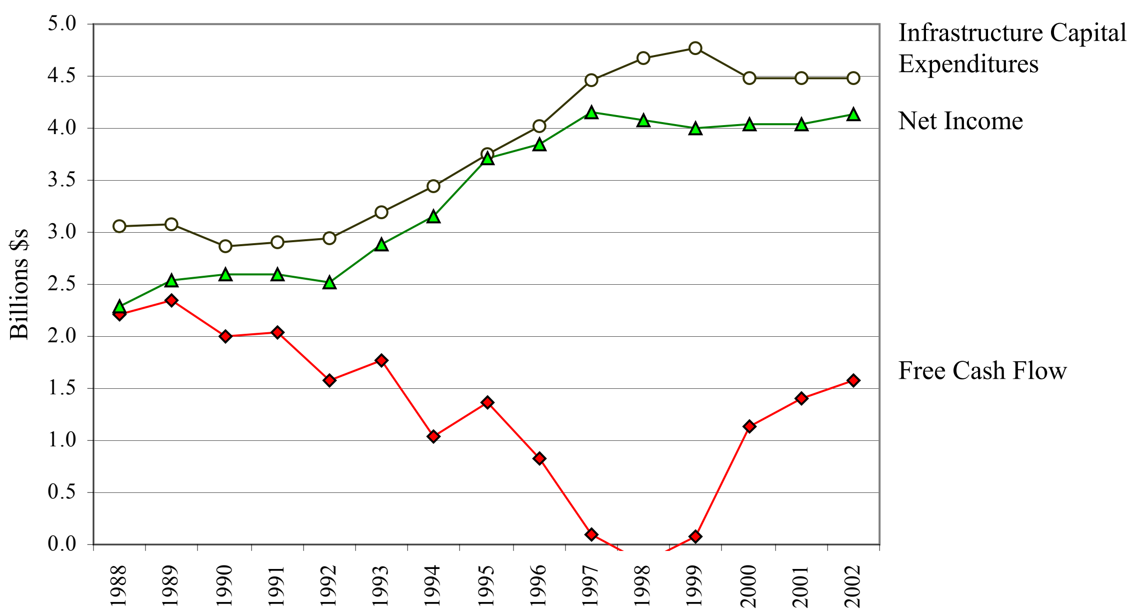

Figure 4.8: Class I Infrastructure Capital Expenditures, Net Income and Free Cash Flow (3-year moving average)

4.9 Discussion and Conclusions

This chapter presented a method that estimates the degree to which prices, and in turn, marginal cost estimates, reflect marginal investment and marginal capital expenditures. In Chapter 3, I found that infrastructure capital expenditures, which comprised the majority of annual capital expenditures, was incrementally variable with output and, to that extent, should be treated as a marginal cost. These results indicate that railroads underestimated the variable portion of capital expenditures in the prices they charged for transportation services, implying these were also underestimated in estimates of marginal cost. A failure to include all variable capital expenditures in marginal cost formulae means that railroads may incur economic losses on normally profitable traffic (when making price/volume trade-off decisions or traffic-traffic trade-off decisions) and on traffic thought to be marginally profitable. These types of losses would not be directly observable to the firm (or the pricing manager) except over the long term by comparing trends in net income and free cash flow.

Railroads may not consider capital expenditures, per se, as an incremental cost for several reasons. (1) Regulatory formulae do not recognize annual capital expenditures as part of marginal or variable cost. Although it is likely that substantial improvements have been made in railroad costing methods, these formulae were at one time the foundation for these methods. (2) Railroads have historically attributed costs to specific traffic on an "after-the-fact" basis rather than estimating future costs of traffic (Kneafsey 1975, 145-50). One of the key objectives of railroads in deregulation was the freedom to reduce prices on truck-competitive traffic at a time when excess capacity supported arguments against the inclusion of capital expenditures as an incremental cost (Fair 1972, 51-62). (3) Railroads may also take an engineering (as opposed to an economic) viewpoint that focuses on historical wear and tear when allocating infrastructure costs (AAR 1991, 71) and/or allocate depreciation costs as they recommended in their critique of the Uniform Rail Costing System (URCS) (AAR 1991, 40). (The inclusion of "variable depreciation" could account for the positive value of the *b* estimate.)

The appropriate economic perspective, however, considers all prospective costs as marginal costs if they are related to prospective traffic. Railroads may consider capital costs (as marginal costs) if they can be directly associated with a specific movement, however, such instances are not typical. The majority of capital expenditures that support overall traffic demand come in relatively small increments, and allocation of future capital costs (other than direct wear and tear) to this type of traffic is difficult and may appear arbitrary to the railroad cost analyst. For example, how would the analyst allocate the cost of a new bridge deck to specific shipments? From one viewpoint, the improvement is clearly a fixed capital cost required to keep the specific route open, and not directly attributable to any particular traffic. However, when considering the alternatives available given the need to replace a thousand bridges in the future, this type of capital cost would appear far more variable.

A failure to sufficiently include all variable capital expenditures in marginal costs could account for the situation that freight railroads face today: the inability to generate sufficient return on investment necessary to justify increasing or even current levels of capital expenditures. Including variable capital expenditures in marginal cost and pricing formulae could eventually force overall price levels up and cause a shift of some traffic to alternative transportation modes. Nevertheless, marginal cost formulae must correctly incorporate all variable capital expenditures to establish efficient prices, investment and production levels.

The estimates of *b* for each period (0.141 and 0.195, respectively) appear (intuitively) low assuming that railroads include a substantial portion of depreciation expense (at current price levels) in their estimates of marginal cost. The extent to which they do so is not observable at this point, and detailed research into their methods could confirm or modify the assumptions, theory and/or methods used for these estimates.

At present, rail prices are starting to rise as capacity in the rail network continues to tighten. Rising prices will undoubtedly reduce the industry's capital deficit, but unless cost formulae are corrected to properly reflect all incremental capital expenditures, railroads will continue to pursue sub-optimal pricing and investment strategies. In other words, even if prices rise substantially, incorrect cost formulae lead to inefficient prices that result in inefficient resource allocation (in this instance, inefficiently allocated capital). Even if the industry is able to raise prices to the point where its current capital deficit becomes a capital surplus, it still cannot optimize return on investment unless marginal cost estimates include all marginal investment costs.

4.10 Appendix

4.10.1 Model Form

The Fixed Effects Model form was chosen to control for omitted variable bias in the estimation of the coefficients for TGTM. This model form uses dummy variables for each firm where the dummy variable coefficient captures the distinct firm effects separately from time effects. These differential firm effects reflect cross-railroad differences that did not change over time, such as network configuration, geographic location, market type, and management characteristics. The differential time effects capture variation that is constant across railroads, such as changes in macroeconomic conditions, regulatory environment, productivity trends, labor contracts, and changes in technology.

Daniel Westbrook, Professor of Economics at Georgetown University, who was contracted by the ICC to evaluate and test URCS, also decided that the Fixed Effects Model was the most appropriate form for this set of panel data in his study of URCS (Westbrook 1998). Kennedy recommends using the Fixed Effects Model if "the data exhaust the population" (sic) as they do in this instance (Kennedy 1998, 227).

4.10.2 Error Components

It is common with panel data to think of the error term as a composite of the variation in each dimension, in this instance across both firms and time (years). The concern with panel data is that a component of the composite error term may be correlated with the explanatory variables. Specifically, if $e_{it} = c_i + u_{it}$, is c_i (the individual specific time invariant effect) correlated with the explanatory variables? Because I chose a Fixed Effects Model with dummy variables for each firm, I have effectively decomposed these errors so that c_i is represented in the dummy variable coefficients and not in the composite error term. This error component (c_i), represents the unobserved attributes of the individual firms that do not vary across time. Wooldridge (2002, 272-3) provided a thorough discussion of the dummy variable regression and illustrated that c_i (or more precisely, $\hat{c}_1$, $\hat{c}_2$, $\hat{c}_3$, etc.) became the coefficient for each dummy variable for each firm.

4.10.3 Auto correlation tests

Tests for autocorrelation were conducted for regression estimates of NI, FCF, and FCF_{CE} on Thousand Gross Ton Miles (TGTM) using balanced panel data for 8 railroads over 15 years. Autocorrelation is a systematic pattern in regression errors and may be negative or positive. With time series data, there is a possibility that successive errors will be correlated to each other meaning that, in any one period, the current error term may contain not only the effects of current shocks but also the carryover from previous shocks. The carryover will be related to, or correlated with, the effects of earlier shocks. This pattern violates one of the fundamental assumptions of the linear regression model. The most common model is the first order autocorrelation process, or AR(1) for short (Griffiths 1993, 517). That is:

$$e_t = \rho e_{t+1} + \upsilon_t$$

where:

ρ = autocorrelation coefficient

υ = error term with constant variance

In this instance, ρ is the carryover of the random error term from the previous period, where ρ determines the degree of carryover. According to Monte Carlo studies, if ρ is less than 0.26, then OLS is the recommended estimation procedure, otherwise EGLS should be used (Irwin 2003a).

To determine if the regression models should be transformed using Estimated Generalized Least Squares (EGLS), ρ was estimated using the following procedure:

(1) Data for the two periods (1988-1998 and 1999-2002) was combined (i.e., 1988-2002). OLS regression was used to estimate coefficients for NI FCF, and FCF_{CE} on TGTM (Tables 4.11 and 4.12).

Table 4.11**:** Regression of NI and FCF on TGTM

Model 4.1					Model 4.2				
$NI_t = TGTM_t + firm$					$FCF_t = TGTM_t + firm$				
Regression Statistics					Regression Statistics				
Multiple R			0.916		Multiple R			0.472	
R Square			0.840		R Square			0.223	
Adjusted R Square			0.819		Adjusted R Square			0.157	
Standard Error			1.82E+05		Standard Error			3.48E+05	
Observations			118		Observations			118	
ANOVA					ANOVA				
	Df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	9	1.88E+13	2.09E+12	63.47	Regression	9	3.79E+12	4.22E+11	3.48
Residual	109	3.60E+12	3.30E+10		Residual	109	1.32E+13	1.21E+11	
Total	118	2.24E+13			Total	118	1.70E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
$TGTM_t$	0.0022	0.0002	10.5017	3E-18	$TGTM_t$	-0.0011	0.0004	-2.6385	0.00955
UP	-1,012,204	186,800	-5.419	0.000	UP	1,235,099	358,178	3.448	0.001
BNSF	-829,043	168,463	-4.921	0.000	BNSF	1,257,961	323,017	3.894	0.000
CSX	-431,477	90,109	-4.788	0.000	CSX	594,556	172,779	3.441	0.001
NS	70,322	74,152	0.948	0.345	NS	490,111	142,182	3.447	0.001
KCS	-10,719	47,396	-0.226	0.822	KCS	47,290	90,879	0.520	0.604
IC	31,530	49,309	0.639	0.524	IC	61,753	94,546	0.653	0.515
SOO	-67,510	47,753	-1.414	0.160	SOO	56,479	91,563	0.617	0.539
GTW	-53,754	48,707	-1.104	0.272	GTW	10,495	93,392	0.112	0.911

Table 4.12: Regression of FCF_{CE} on TGTM

Model 4.3

$FCF_{CEt} = TGTM_t + firm$

Regression Statistics	
Multiple R	0.439
Square	0.193
Adjusted R Square	0.125
Standard Error	2.52E+05
Observations	118

ANOVA

	df	*SS*	*MS*	*F*
Regression	9	1.66E+12	1.84E+11	2.90
Residual	109	6.94E+12	6.37E+10	
Total	118	8.60E+12		

Variable	*Coef.*	*SE*	*t*	*p*
$TGTM_t$	0.0001	0.0003	0.2345	0.815
UP	79,531	259,555	0.306	0.760
BNSF	65,980	234,075	0.282	0.779
CSX	-102,226	125,205	-0.816	0.416
NS	280,225	103,032	2.720	0.008
KCS	-21,636	65,856	-0.329	0.743
IC	31,052	68,513	0.453	0.651
SOO	-40,694	66,351	-0.613	0.541
GTW	-38,459	67,677	-0.568	0.571

(2) NI, FCF, and FCF_{CE} were then estimated for each year and each railroad (i.e., NI^, FCF^, and FCF_{CE}^).

(3) The error for each year was computed by subtracting the estimated values for NI, FCF, and FCF_{CE} from the actual values (i.e., $NI\hat{e}_t$, $FCF\hat{e}_t$, $FCF_{CE}\hat{e}_t$)

(4) The error associated with a one-year lag was regressed on the error for the current year. Data for the year 1988 was dropped because there was no previous year, reducing the number of observations from 118 to 110 (Tables 4.13 and 4.14).

Table 4.13: Regression of NI and FCF errors

Model 4.4					Model 4.5				
$NI\hat{e}_t = \rho NI\hat{e}_{t-1} + \upsilon_t$					$FCF\hat{e}_t = \rho FCF\hat{e}_{t-1} + \upsilon_t$				
Regression Statistics					Regression Statistics				
Multiple R			0.141		Multiple R			0.014	
R Square			0.020		R Square			0.000	
Adjusted R Square			0.011		Adjusted R Square			-0.009	
Standard Error			1.80E+05		Standard Error			3.48E+05	
Observations			110		Observations			110	
ANOVA					ANOVA				
	df	*SS*	*MS*	*F*		*df*	*SS*	*MS*	*F*
Regression	1	7.02E+10	7.02E+10	2.18	Regression	1	2.69E+09	2.69E+09	0.02
Residual	108	3.48E+12	3.22E+10		Residual	108	1.31E+13	1.21E+11	
Total	109	3.55E+12			Total	109	1.31E+13		
Variable	*Coef.*	*SE*	*t*	*p*	*Variable*	*Coef.*	*SE*	*t*	*p*
Intercept	3,911	17,129	0.228	0.820	Intercept	-4,342	33,233	-0.131	0.896
ρ	0.137	0.093	1.476	0.143	ρ	0.015	0.098	0.149	0.882

Table 4.14: Regression of FCF_{CE} errors

Model 4.6				
$FCF_{CE}\hat{e}_t = \rho FCF_{CE}\hat{e}_{t-1} + \upsilon_t$				
Regression Statistics				
Multiple R			0.217	
R Square			0.047	
Adjusted R Square			0.038	
Standard Error			3.71E+05	
Observations			110	
ANOVA				
	df	*SS*	*MS*	*F*
Regression	1	7.34E+11	7.34E+11	5.34
Residual	108	1.49E+13	1.38E+11	
Total	109	1.56E+13		
Variable	*Coef.*	*SE*	*t*	*p*
Intercept	69,940	36,422	1.920	0.057
ρ	0.215	0.093	2.310	0.023

In all cases ρ was less than 0.26. Accordingly, OLS is the recommended procedure for estimating NI, FCF, and FCF_{CE} with respect to Gross Ton Miles.

4.10.4 Heteroskedasticity correction

One of the assumptions of the classical linear regression model is that the variance of the error term is constant (homoskedastic). When this assumption is violated, the variance of the error term is not constant (heteroskedastic) (Irwin 2003b).

Heteroskedasticity can arise in cross sectional data as a result of scale effects, for example, larger railroads may behave somewhat differently than smaller railroads. It can also arise in time series data as the result of learning curves or changes in technology. For my purposes, the primary concern is with scale effects associated with railroads of different sizes.

When the errors are heteroskedastic, the least squares estimator is still linear and unbiased, but the least squares estimator is no longer minimum variance. The standard errors produced by least squares procedures are inappropriate (Griffiths 1993, 485). The standard error will be biased, but the direction of the bias cannot be predicted.

One method to seek the correct estimate of standard error in such instances is the use of *White's Approximate Estimator*. In this method, the variance (σ_t^2) is replaced with the estimated error term squared ($\hat{e}_t^2$). White's argument was that large variances were likely to lead to large estimated squared residuals. Because of this approximation, White standard error estimates are valid only with large sample sizes and are sometimes called heteroskedastic-consistent variance-covariance estimates.

To calculate White's Approximate Estimator, the following process was used:

(1) Gross Ton Miles for each railroad and each period (1988-1998 and 1999-2002) were averaged and subtracted from GTM for each year and then squared and summed ($\Sigma\{x_t - x_t\text{bar}\}^2$).

(2) This amount ($\{x_t - x_t\text{bar}\}^2$) was then multiplied by the estimated error squared ($\hat{e}_t^2$).

(3) This amount $[\Sigma\{x_t - x_t\text{bar}\}^2 \cdot \hat{e}_t^2]$ was then divided by the sum of $\{x_t - x_t\text{bar}\}^2$ for each time period *within* the railroad sample and then squared, that is: $(\Sigma\{x_t - x_t\text{bar}\}^2)(\hat{e}_t^2) / [\Sigma\{x_t - x_t\text{bar}\}^2]^2$. This is White's variance estimator.

The results are shown in Table 4.15 below.

Table 4.15**:** Comparison of White's and OLS Standard Errors

	Model 4.1 $NI_t = TGTM_t + firm$		Model 4.2 $FCF_t = TGTM_t + firm$		Model 4.3 $FCF_{CEt} = TGTM_t + firm$	
Period	*Least Squares SE*	*White's SE*	*Least Squares SE*	*White's SE*	*Least Squares SE*	*White's SE*
1988-2002	0.00021	0.00049	0.00040	0.00000	0.00029	0.00066
1988-1998	0.00036	0.00051	0.00061	0.00000	0.00045	0.00068
1999-2002	**0.00131**	**0.00108**	0.00136	0.00000	0.00116	0.00124

The estimate with the variance of concern was Model 4.1 for the period 1999-2002 (shown in bold in Table 4.15). White's estimator indicates that the actual variance is smaller than the least squares variance, meaning that the 95% confidence interval is actually less than that estimated by OLS.

The same process was conducted for the railroads within each time period. In other words, a correction was made for heteroskedasticity in the time (as opposed to the firm) dimension. In step 1, Gross Ton Miles for each year were averaged among the railroads for each year and subtracted from GTM for each year. In all cases, the White's estimator indicated a smaller variance than either the least squares standard error estimate or the White's standard error estimate within the firm dimension.

4.10.5 Railroad Cost of Capital

A company's cost of capital is the cost of the individual sources of capital, weighted by their importance in the firm's capital structure (Higgins 2004, 280). It is also defined as the expected return on a portfolio of all the company's existing securities (Brealey and Myers 2003, 222). From a shareholder perspective, management creates value when it earns returns above a firm's cost of capital and destroys value when it earns returns below this target (Higgins 2004, 281). The two general sources of capital to a firm are debt and equity. The cost of debt is fairly easy to calculate, but the cost of equity is more difficult because it incorporates expectations of shareholders (Higgins 2004, 282).

The cost of common equity, Ks, is also called the cost of common stock. It is the rate of return required by the firm's stockholders, and can be estimated by three methods: (1) the CAPM approach, (2) the dividend-yield-plus-growth-rate, or DCF approach, and (3) the bond-yield-plus-risk-premium approach (Brigham and Ehrhardt 2002, 451). The cost of equity derivation for each model is used in connection with the cost of debt to estimate the weighted average cost of capital (WACC).

DCF is considered appropriate for mature, stable companies where dividend yield growth can be forecasted with some accuracy (Brealey and Myers 2003, 65). DCF uses a combination of dividend yield and a growth factor based on earnings forecasts to estimate the cost of equity capital. The AAR estimates a cost of capital for the railroad industry using a constant-growth DCF.

Earlier academic textbook writers referred to the dividend-yield-plus-growth-rate model as the Gordon Model (Gordon 1962) or the Dividend Discount Model (DDM). Gordon's Model was an extension of the intrinsic valuation model developed by John Burr Williams (Williams 1938). The modern approach is to refer to it as the DCF approach or the dividend-yield-plus-growth-rate model.

CAPM and the bond-yield-plus-risk-premium approaches calculate the cost of equity using the stock's beta, a measure of a firm's market risk. Difficulties with these approaches often come from the degree of precision with which the beta can be estimated if standard errors are large.

The Interstate Commerce Commission (1983b, 4-6) conducted several hearings in 1983 to determine the appropriate method to estimate the railroad industry's cost of capital. With one exception, the expert witnesses rejected the CAPM method. Additionally, the shippers at these hearing objected to the use of the CAPM. The overall method for determining the industry weighted average cost of capital (using the DCF method) is discussed in the following paragraphs and includes a comparison to the CAPM approach using recent financial data.

Substantial portions of the following discussion come from AAR testimony (2004) on the calculation of the industry's cost of capital.

Annual Determination of Railroad Industry Cost of Capital: The AAR computes a cost of capital for the railroad industry each year and submits this calculation to the STB for approval. Specifically the AAR calculates the cost of common equity capital and the cost of capital of the railroad industry incorporating the cost of debt, cost of preferred equity, and market value capital structure mix of the railroad industry as computed by the AAR using procedures accepted in previous STB proceedings.

The Composite Railroad Approach: The AAR uses a composite railroad approach to computing an industry-wide cost of capital. This approach relies upon data from a sample of railroads meeting criteria established by the STB. The composite approach is considered statistically and economically sound for several reasons. First, the current cost of investment-grade debt does not vary significantly among major railroads. Second, while there may be estimation errors associated with the direct measurement of the cost of equity for individual railroads, industry-wide calculation tends to average out such errors. Third, financial theory indicates that, when computing the cost of capital based on current debt costs, increases (or decreases) in the debt/equity ratio cause corresponding increases (or decreases) in the cost of equity that result in a relatively stable current cost of capital. This relationship stems from the fact that as the percentage of debt in the capital structure increases, the cost of equity also increases because of the increased risk. "Use of an industry-wide debt/equity ratio and industry-wide costs of debt and equity are, therefore, appropriate" (AAR 2004, 4).

Types of Railroad Capital: A firm's overall cost of capital is the opportunity cost of the funds available to the firm and to its investors. As an alternative to investing in a new project of average risk, a firm could repurchase a fraction of its outstanding securities at prevailing market prices. Because the expected rate of return on the total market value of a firm's outstanding securities reflects the opportunity cost of funds used in repurchasing such securities, the expected rate of return on the total market value of the firm's outstanding securities is equal to its overall cost of capital. The total capital of a firm includes common and preferred stock (equity), as well as debt. Each of these three sources of capital have different expected rates of return, and thus the overall cost of capital is a market value of the weighted average of the costs of common equity, preferred equity, and debt (AAR 2004, 6-7).

The Cost of Common Equity Capital using DCF Method: The cost of equity is the opportunity cost of investing in a share of a firm's stock: i.e., the expected rate of return, which investors require on the market value (purchase price) of the stock in light of alternative investment opportunities of comparable risk. Because investor expectations are not directly observable, analysts have developed methods of inferring the cost of equity from available financial data. The DCF method used by the AAR relies on observed stock prices and analysts' growth forecasts. "The DCF method is recognized as a valid approach to measuring the cost of equity by the overwhelming majority of financial experts in the country, and among federal and state regulatory agencies it is the most widely used method for determining the cost of equity" (AAR 2004, 7).

The AAR calculated the 2002 market value of common equity by multiplying the number of shares outstanding by the daily closing price for each trading day during the year for each of the sample railroad holding companies. The AAR determined the average market value for the year 2001 was $40.836 billion, which was confirmed by the STB.

The DCF method requires an estimate of expected growth in earnings (the "g" component of the formula), and the AAR uses growth rate data developed by the Institutional Brokers Estimate System (IBES) for this purpose. The cost of equity under this method is the discount rate which makes the present value of all expected returns from holding the stock, including both dividends and price appreciation equal to the stock's current market value. The DCF method of determining the cost of common equity is used by the majority of state regulatory agencies and has been used by the ICC and STB for many years.

In formulaic terms, the firm's cost of equity capital may be expressed as:

$$K = (D_1/P_0) + g$$

where:

K = the firm's cost of equity

D_1 = the prospective annual dividend

P_0 = the current price of the firm's stock, and

g = the expected rate of earnings growth, used as a proxy for dividend growth

The two terms in the formula correspond to the two forms of return from holding a stock – namely, dividends and price appreciation. The first term, D_1/P_0, is the expected dividend yield. The price appreciation component (g) arises from the growth in the firm's earnings and dividends over time. If the earnings of the firm grow at a rate of g, and if the earnings/price ratio of the firm's stock remain constant, the value of a share in the firm would also grow at a rate of g (AAR 2004, 7-9).

Composite Growth Rate: The STB uses a consensus of security analysts' forecasts to obtain an estimate of the composite growth rate over a five-year time horizon. The g component of the DCF formula measures investor's expectations, and a consensus of analysts' forecasts is considered by the STB as the most accurate method available for estimating those expectations.

In its decision in Ex Parte No. 473, the STB expressed a preference for use of consensus analysts' five-year earnings-per-share forecasts that was employed in previous proceedings. The AAR employs IBES data in determining the composite growth rate and a truncated average of IBES survey forecasts wherein extreme values are excluded from the average. The truncated average is calculated for each month and then averaged over the annual period. From IBES data, the following are determined for each sample railroad for each of the 12 sample months: a simple average, the highest forecast, the lowest forecast, and a number of forecasts (AAR 2004, 9-12).

The percent composite growth estimate is calculated as follows:

1) A simple average is computed from the IBES estimates based on monthly averages for each railroad.
2) The high and low rates are deleted in each month for each railroad and a truncated simple average is derived,
3) Railroad weights are calculated using average daily closing prices and the number of shares outstanding at the end of each quarter (as reported by the

sample railroads). Quarterly data is adjusted with specific monthly data when there are changes in the number of shares of common stock; and

4) The weights for each railroad are multiplied by each railroad's truncated average to derive in a weighted average, truncated growth rate.

In 2002, the AAR concluded that the composite earnings per share growth rate was 11.12% based on a truncated average of the forecasts for each company (STB 2003, 7).

Composite Dividend Yield: The AAR determines a composite dividend yield for the railroad industry from an average of the dividends paid each month divided by an average of the stock prices for that month. The daily closing stock prices are obtained from Dow Jones News/Retrieval Services. In 2002, the AAR developed a composite dividend yield of 1.40% for 2002, which was confirmed by the STB (AAR 2004, 12).
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Cost of Debt: The cost of debt calculation includes market values of bonds, notes, debentures, equipment trust certificates, and conditional sales agreements. Other debt and capitalized leases are included at their book value, because market values are difficult to determine (in some instances book values correspond to market values) and because their other instruments are a minimal portion of all debt.

AAR/STB's Estimate of the Composite Cost of Capital: In summary, the AAR and STB concluded that for 2002 (STB 2004, 9-10):

1. The cost of railroad long-term debt equaled 6.0%.
2. The cost of common equity equaled 12.6%.
3. The cost of preferred equity equaled 6.3%.
4. The capital structure mix of the railroads equals 41.2% long-term debt, 56.7% common equity, and 2.1% preferred equity.
5. The composite railroad industry cost of capital equaled 9.8%.

Discussion of AAR/STB Cost of Capital Estimates: Although the DCF method is accepted for regulatory purposes, questions arise as to the growth rate (g) used to calculate the cost of common equity. A growth rate of 11.12% appears intuitively high for the railroad industry, especially given the long-run differences between the growth rate of earnings and the growth rate in free cash flow. If the true value of the firm is related to the net present value of free cash flows, then the growth rate used in these calculations should be related to free cash flow growth, not earnings. It is generally assumed that earnings and free cash flow growth rates are related, but because earning are generally more stable than free cash flow, earnings are used to estimate growth trends. Given the large disparity between net income and free cash flow trends in the railroad industry, however, this assumption should be questioned.

Alternative Estimates using Capital Asset Pricing Model: The Capital Asset Pricing Model calculates the cost of equity using the stock's beta, a measure of market risk. One way to measure the beta (β) of a stock is to estimate the variance of its total rate of return (dividends and capital gain) in prior years with respect to the variance of market index returns. The beta tells us how much on average the stock price changed for each additional 1 percent change in the market index. To illustrate how this works, Brealey estimated the returns expected by investors in July 2001 for a sample of stocks (Table 4.16).

Table 4.16: Estimated betas and expected returns

	β_{equity}	Expected Return
Amazon.com	3.25	29.5%
General Motors	0.91	10.8%
McDonald's	0.68	8.9%

Source: Brealey and Myers. 2003. Principles of Corporate Finance 7th ed., 196.

The estimated betas for large railroad companies is consistently less than 1.0 and, as calculated by Brealey and Myers (2003, 226), averages 0.50 with a standard error of 0.17 (Table 4.17).

Table 4.17: Estimated betas for a sample of large railroad companies

	β_{equity}	Standard Error
Burlington Northern Santa Fe	0.64	0.20
CSX Transportation	0.46	0.24
Norfolk Southern	0.52	0.26
Union Pacific Corp.	0.40	0.21
Industry Portfolio	0.50	0.17

Source: Brealey and Myers. 2003. Principles of Corporate Finance 7th ed., 226.

The capital asset pricing model, developed in the mid-1960's by three economists (William Sharpe, John Lintner, and Jack Treynor) takes into account the risk premium on the stock as shown below:

$$r - r_f = \beta\,(r_m - r_f)$$

where:

r = expected return of firm

r_f = no-risk interest rate (i.e., U.S. Treasury bond rate)

β = beta of a firm

r_m = rate of return on market index

Over a period of 75 years the market risk premium ($r_m - r_f$) has ranged from 6 to 10%. Treasury securities have a beta of 0 and a risk premium of 0.

Brealey estimated the cost of capital for Union Pacific Corporation using the industry average beta of 0.50 in mid-2001 when the risk-free rate of interest was 3.5 percent. The expected return on stock was calculated as follows:

$$\text{Expected stock return} = r = r_f + \beta\,(r_m - r_f)$$
$$= 3.5 + 0.50\,(8.0) = 7.5\%$$

The company cost of capital is the weighted average of the expected returns on the debt and equity:

Company cost of capital = r_{assets} = [debt/(debt+equity)] r_{debt} + [equity/(debt+equity)] r_{equity}

Considering the railroads as a whole and using the 2002 estimated cost of debt for the industry, these Brealey's calculations yield the following result:

CAPM Railroad CoC (2002) = (43.3% • 6.0%) + (56.7% • 7.5%) = 6.85%

However, the standard error for the railroad industry beta (0.17) yields a two standard deviation range with a low of 4.78% and a high of 10.22% in the estimation of cost of capital, as shown below.

$$\text{CoC} (\pm 2\sigma) = 3.5 + [0.50 \pm \{2(0.17)\}]\,(8.0) = 4.78\% — 10.22\%$$

This means that the AAR/STB estimate (9.8%) is within two standard deviations of the CAPM estimate (6.85%).

5.0 Summary and Discussion

"[If Dupuit] had not hidden his light under a bridge, Jevons might have found himself twenty years out of date."

John R. Hicks, "Review of *De l'utilite et sa mesure par Jules Dupuit,*" 1935

"it is definitely the current and future – not the historic – capital costs that are relevant."

Alfred Kahn, 1970

" … beware of arguments that marginal costs are very different from average costs."

Tony Gomez-Ibanez, 1999

5.1 Review of Principal Hypothesis

I proposed that railroad capital expenditures represent an incremental cost of traffic but are largely excluded from marginal cost estimates, and that this results in sub-optimal returns to invested capital. This hypothesis was investigated by combining elements of engineering, economic, and financial theory presented in Chapters 2, 3, and 4. Railroad financial data and operating statistics were employed to test the hypothesis that an emphasis on capital expenditures for infrastructure, the largest component of overall capital expenditures, led to more efficient maintenance regimes. Economic theory and econometric techniques were used to evaluate if capital expenditures for infrastructure were variable with output. Finally, economic and financial theory were combined to determine if railroads had substantially underestimated variable capital expenditures included in their estimates of marginal cost or price floors, and the degree to which they had done so.

I found that infrastructure capital expenditures represented an incremental cost of traffic that was substantially underestimated in railroads' estimates of marginal cost.

5.2 Chapter 2

The question addressed by this chapter is whether there is a relationship between engineering maintenance strategy, in terms of its relative emphasis on renewal or ordinary maintenance (renewal strategy), and the overall cost effectiveness of the maintenance function. The primary hypothesis is that an emphasis on capital expenditures reduces total infrastructure maintenance cost. Alternative hypotheses considered are that size, light density track miles and average network densities are responsible for more efficient maintenance regimes.

The methodology used to test the hypotheses included a model adapted from economic literature to segregate renewal capital expenditures from overall infrastructure capital expenditures. A series of standard statistical tests were conducted using alternative models to forecast unit maintenance cost including variables for renewal capital expenditures, network size (track miles), percent light density track miles, and average network density, or combinations thereof.

The results of these tests did not allow me to reject the primary hypothesis. Tests on the alternative hypotheses indicated that variables for size and average density were influential, but they were secondary to renewal strategy and influential only in combination with renewal strategy. In other words, size and density were significant but secondary factors with respect to renewal strategy, and they were significant only in combination with a renewal strategy in the model.

5.3 Chapter 3

This chapter investigates the relationship between infrastructure capital expenditures and output to determine the degree to which such expenditures should be considered in marginal cost estimates. Specifically, the primary hypothesis is that infrastructure capital expenditures are variable with, and caused by, changes in railroad output. The alternative hypotheses are that Free Cash Flow and Net Income are the primary causal drivers of these capital expenditures (as opposed to output).

The methodology used to test the hypotheses included lag specification and Granger Causality tests, and Vector Auto Regression (VAR) analysis. These tests are generally accepted econometric methods although VAR analysis is a fairly recent innovation.

The results indicated that output was correlated with infrastructure capital expenditures, and that such expenditures were caused by output. In a few instances there was a causal effect of free cash flow and net income on capital expenditures, but these appeared limited to the few instances where financial constraints existed. Additional support for the primary hypothesis was demonstrated by the finding that capital expenditures were a better predictor of net income and free cash flow than was output.

5.4 Chapter 4

This chapter presents a new method to calculate the percentage of capital expenditures that is reflected in railroad prices. The primary hypothesis is that the percentage of variable capital expenditures included in railroad prices is substantially less than 1.0. Alternative hypotheses were tested using a sensitivity analysis by (1) changing the estimates of the variability of operating expenses, (2) reducing the estimated capital deficit, and (3) introducing price incrementalism.

The methodology used to evaluate these hypotheses integrated economic and accounting concepts of cost and then compared trends in net income and free cash flow with respect to output. Although this method was not found in the literature, support for it was developed using economic principles established by Milton Friedman and methods found in cost accounting literature.

The results indicated that railroad price floors and marginal cost estimates substantially and systematically underestimate the true variable nature of ongoing capital expenditures. Alternative scenarios (alternative hypotheses) were tested using sensitivity analyses and the estimated percentage of variable capital expenditures reflected in prices was still considerably less than 1.0. Accordingly, I could not reject the primary hypothesis.

5.5 Origins and Application of Marginal Analysis in the Railroad Industry

The preceding analysis (Chapters 2-4) may be sufficient to support acceptance of (or failure to reject) the principal hypothesis, but a comprehensive analysis warrants further investigation into the potential causes of this mis-interpretation of economic theory. A review of the literature provides some clues.

Jules Dupuit, a graduate of the French School of Engineering (Ecole des Ponts et Chausses) in 1827, concerned himself with economic problems throughout his career as an engineer. He was one of the most distinguished civil engineers of his time and had an equally remarkable career as an economist. His contributions to the field of economics were primarily related to his responsibility as an engineer of public works, primarily transportation infrastructure. In 1844, Dupuit was the first economist to present a cogent discussion of the concept of marginal utility by combining the concepts of intrinsic utility and scarcity. In doing so, he defined the concept of value and related it to a demand curve. Furthermore, he was able to relate concepts of marginal utility and marginal cost. Dupuit's rule for the provision of public goods, including railways, was that goods should be provided if the marginal annual receipts of an enterprise could cover the marginal costs (including capital costs) (Ekelund and Hebert 1999, 136). Among his insights are two concepts of particular interest to this research. First is the concept that marginal cost includes a component for capital costs (Ekelund and Hebert 1983, 270). Second is the notion that marginal cost is forward looking, in other words, what belongs in the marginal cost calculation is the amount by which costs will be higher as a result of incremental production.

Preceding Dupuit's development of marginal utility in 1844 were a series of French econo-engineers, including Dutens, Navier, and Minard, that formulated benefit-cost theory as a decision rule determining when to provide a public good (Ekelund and Hebert 1999, 89). In such calculations, capital, upkeep and renovation were all costs that must be considered. Capital costs were not considered different than upkeep or renovation costs except in their periodicity.

Regulation of railroad rates, beginning in early 20th century, created the need to assess the reasonableness of a specific rate in relation to the shipment's variable cost. In the 1920's and 1930's the Interstate Commerce Commission (ICC) dealt with individual cases requiring variable cost estimates. These individual estimates of variable cost led to the need for a universal methodology to estimate variable costs. In 1939, the ICC's Section on Cost Finding, led by Ford Edwards, developed a universal and comprehensive methodology to estimate carload costs (ICC 1941a, 3-5).

The ICC's cost procedure, called Rail Form A (RFA), was designed to estimate variable costs in the medium term. To account for the medium-run viewpoint (as opposed to a short-run viewpoint), Edwards included a return for 100% of equipment investment and 50% of infrastructure investment in RFA cost formulae. Annual capital expenditures were not considered incremental (or variable) costs, per se, regardless of whether business levels were expanding or contracting (ICC 1943).

Later authors took exception to the inclusion of a return on capital in RFA variable cost estimates. They advised railroad management to use a narrow definition of variable capital expenditures. Edward Poole published *Costs – A Tool for Railroad Management* (1962, 20-27) in which he stated: "To consider 50% of the return on fixed property as variable with the volume of business or out-of-pocket, is to draw conclusions without analysis. ... capital expenditures are made both for increases in plant capacity and for improvements to effect economies. Expenditures to accommodate growing business are, of course, variable, … but capital expenditures to effect economies do not fall into this category." Poole argued that efficiencies obtained from any improvement offset its inclusion in variable cost. "When the capacity of a track has increased to a point where a second track is required for a particular section, an out-of-pocket cost (from the capital cost) added to all traffic is not warranted. … The traffic over the 100-mile section should provide sufficient margin of profit to cover the return on the added investment required in that section. … In any event, when a single track has reached its capacity and a second track is necessary, there are substantial out-of-pocket operating savings realized from the second track, usually enough to cover the return plus a profit, without the necessity for any extra costs to be assessed on existing traffic in advance of the installation. … Expenditures to provide technological improvements in maintenance and operation do not increase out-of-pocket costs, instead they decrease these costs." His definition thereby eliminated consideration of virtually all capital expenditures from consideration as a marginal cost, even when such expenditures were incurred to expand capacity.

In 1964, the Association of American Railroads (AAR) went further in narrowing the definition of incremental capital costs (AAR 1964). One of the key authors of the 1964 study was Ford Edwards, who was also the key author of the original 1939 ICC study leading to Rail Form A.

> Only those incremental capital costs which can be associated with (i.e., traced to) particular movements are properly a part of cost floors for pricing. … This contribution should be judged independently … rather than being packed arbitrarily into floor-cost calculations by some average apportionment of irrelevant factors such as unallocable 'return' on investment. These customary procedures under Rail Form A usually give the resulting cost calculations an upward bias. … To the extent that new investment will have to be incurred or it is reasonably clear that investment in existing facilities will have to be replaced in the foreseeable future as a consequence of the movement of particular traffic increments, the cost of such investment is properly included with other incremental (variable) costs of that traffic in determining the minimum requirements of a compensatory rule. … That a large amount of unused capacity exists in the railroads' facilities, especially in their basic plant is generally recognized. The prevalence of this condition is indicated by the fact that the average mile of road in the United States accommodates only five trains a day in both directions combined. … What this means is that increases in traffic could be handled with little or no additional capital investment in plant capacity and, conversely, that reduced traffic volume would not bring commensurate reduction in railroad capital investment because of the general indivisibility of railroad plant facilities. … Most railroad plant investments in recent years have, indeed, been made not in response to or anticipation of changes in traffic volume but as part of cost reduction programs. 'Return' on such investments cannot be properly

included as a volume-induced incremental cost of capital in establishing cost floors for the pricing of particular traffic. … the superficial use of statistical correlation techniques, assuming a causal relationship between capital investments and traffic volume changes to the exclusion of other responsible factors, will fail to identify and will usually exaggerate those incremental costs of capital which are the consequence of volume change alone. Moreover, if some standardized allowance for 'return,' which includes the computed costs of capital on current investments made primarily for cost reduction purposes, is added to historical operating costs which do not reflect lower future operating costs, there will be a persistent bias in the direction of overestimating the relevant measure of incremental cost.

The problem with excluding capital expenditures that reduce operating expense from marginal cost estimates is illustrated as follows. Suppose that a capital expenditure is made that reduces operating expenses and, as a result, the contribution ratio of a particular movement increases from 180 to 200 if the incremental capital costs are not included in marginal cost estimate. The pricing manager will make price volume trade-off decisions based on the new contribution ratio of 200. Suppose that the actual contribution ratio, including the incremental capital expenditure, is 190. As illustrated in section 4.8, if the pricing manager makes pricing decisions using a contribution ratio that is overstated, because marginal cost is understated, economic losses may occur, in this case because the pricing manager is using a contribution ratio of 200 instead of 190.

The AAR report cited a publication by W. J. Baumol, *The Role of Cost in the Minimum Pricing of Railroad Services*, as its theoretical foundation (Baumol et al. 1962). This is perplexing because Baumol's definition of incremental cost was far from the narrow version offered in the 1964 AAR report. Baumol stated, "The increase in *total costs* resulting from an expansion in a firm's volume of business is commonly referred to as incremental cost."

In practice, the AAR's definition of incremental cost excluded virtually all infrastructure capital expenditures because very few of these improvements resulted from a particular traffic increment. Additionally, almost every infrastructure improvement has some element of cost savings associated with it. In contrast, Baumol made no such distinction in his definition of incremental cost. By establishing the twin requirements of direct causation and not-for-cost-reduction before capital expenditures could be considered variable, the AAR's guidance may have been responsible for later misinterpretation of the role of capital expenditures in marginal cost estimates when business conditions changed.

Kneafsey (1975, 145-50) concisely described the problem although the situation may have been reversed at the time.

> The historical emphasis has been on attributing costs to specific operations on an 'after the fact' basis … It is important in developing contemporary pricing strategies for the railroads to distinguish between concepts of cost that are applied in an historical accounting context and concepts of costs that are applied to an estimation of future costs. While the concept in each instance may sound similar in application, they clearly differ in substance.

Railroads had been experiencing a long period of excess capacity and wanted to reverse the long-run decline in traffic volume. Passenger service was disappearing, highway traffic was growing, and railroads needed flexibility to lower rates to compete with highway/waterway traffic. The ICC mandated minimum rates on the basis of RFA (when complaints were made), and RFA included ROI in variable cost estimates. But ROI is not a variable cost in that it does not represent a prospective outlay of funds (it is an opportunity cost of past expenditures). By including ROI, the ICC's mandated minimum rate levels were above railroad marginal costs. This kept railroads from competing for marginal highway/waterway traffic from which they could have earned some surplus revenue over and above marginal cost. The railroads' (understandable) frustration with the inclusion of a return on investment in rate floors may have led to confusion about the nature of the problem.

The ICC erred in two related, but fundamentally different ways. First, by including "variable ROI" in cost formulae and in mandated minimum rate levels, it was using (or thought it was using) “average variable costs” (instead of marginal costs) to set price floors. By using average cost criteria in place of short-run incremental costs, regulated price floors deprived railroads of needed marginal revenue. Second, RFA excluded variable capital expenditures (only variable expense) in variable cost calculations. The cost accountants that designed RFA apparently did not consider capital outlays a variable cost, and may have felt that including “variable ROI” took care of the investment side on the variable cost calculation.

In summary, the ICC erred first by using the wrong mechanism to set price floors, and secondly in the way it estimated variable costs. These errors may have been generally offsetting (in terms of revenue) when railroads faced weak intermodal competition. Furthermore, in combination, the economic distinction between them may have been muddled. Although both involve “investment”, marginal analysis treats them very differently because one is prospective (capital expenditures) and the other is retrospective (ROI). It appears that there was confusion about the inherent differences between these two viewpoints.

When highway and waterway competition began to drain away revenues, the railroads knew they needed the flexibility to price services at or near marginal cost, and that this should not include ROI. In their drive to get at marginal pricing, they may have lumped ROI and incremental capital expenditures together as inappropriate for price floor calculations not recognizing the different economic principles at work. This confusion may not have been terribly important in the 1960’s when capacity was overbuilt and capital expenditures were less substantial, but it sowed the seeds that may be at the root of their economic problems today.

Following deregulation in 1980, railroad conditions changed: (1) unused capacity was largely eliminated, (2) renewal maintenance became capitalized as a result of the 1981 tax act, (3) railroads became far more reliant on renewal investment as a more efficient way to maintain infrastructure, and (4) capital expenditures grew rapidly with output. As a result, the exclusion of incremental capital costs (in marginal costs and price floors) may have resulted in deteriorating economic performance even though income and output were growing.

5.6 Marginal Analysis and Engineering Practice

Part of the explanation for the mis-interpretation of investment variability may be the apparent lumpiness of many infrastructure investments. The production of transportation requires a broad range of resources, some of which are added in minute increments (fuel, labor, materials and supplies) and others that are added in larger increments (equipment, infrastructure). Transportation economists often think of infrastructure as being provided in large increments necessary for minimum network operation (replacement of bridges, rail) or for capacity improvements (second mainline, terminal or yard, centralized traffic control systems). It is those infrastructure components that come in large or "lumpy" increments that require further clarification to illustrate their true marginal characteristics.

Bridges were often discussed by Dupuit, and provide a good example of a production factor that appears to be fixed regardless of output. Bridges normally have long life cycles; many in use today are over 100 years old. They are not easy to pick up and move and are built for a particular site. Financial managers have argued that bridges are a fixed factor (or cost) because they are essential to any movement of traffic.

Things look different from an engineering viewpoint. The railroad's operating department has a number of alternatives given the size and scope of the network. Even the railroad engineer has a number of alternatives for a bridge needing replacement. A hypothetical example of the capital budget process and the engineer's decision framework is used to illustrate this concept.

Each year the Bridge and Building (B&B) Manager submits a request for capital funds for bridge replacements (along with other capital budget requests) to higher engineering management. The capital budget request goes from the B&B Manager to the Chief Engineer to the Vice President (VP) Engineering to the VP Operations. At each level, it is added to other requests, and at each stage there is a reduction in the total "wish list." The VP Operations consults the VP of Marketing to obtain a forecast of future demand, and adjusts capital spending priorities accordingly. The VP Finance establishes a reasonable level of overall capital funding given a number of factors including engineering priorities, financial indicators, the expected market demand, future revenues, changes in expected operating expenses, dividend needs, and goals and incentives of senior management. The VP Operations then apportions the available capital budget among his departments (i.e., engineering, mechanical, risk management, etc.), and each layer of hierarchy allocates the available budget based on its relative priorities.

In this process, the railroad's managers balance the overall capital budget (determined from anticipated demand) with overall capital needs (based on condition of assets), the difference resulting in (more or less) slow orders, weight restrictions, and/or maintenance expense. Asset conditions being equal, those route segments that have higher traffic levels will receive more capital resources than those segments with less traffic. Capital resources will be allocated based upon a number of factors (e.g., traffic demand, asset condition, risk, anticipated effects on future operations, and maintenance expenses).

The B&B Manager has a number of alternatives for capital budget items that were not approved. He can add braces and supports, weld fatigue cracks, and use other means to extend the life of the bridge. A "slow order" may be issued causing trains to operate at lower speeds when crossing the bridge. These actions may add to operating expenses for both the engineering and transportation department, but the capital expenditure is rarely an absolutely immediate necessity. In almost all cases, it is justified on the basis of controlling what would otherwise be considered variable maintenance and operating expenses.

What principles should determine when a specific capital expenditure should be treated as an incremental cost, particularly if it is long-lived or lumpy? One method is to look at the set of alternatives available to the transportation engineer.

In the example of the bridge replacement, the B&B Manager has several choices, for example:

- Implement slow orders to reduce dynamic loads,
- Increase the frequency of inspection and repair,
- Renew only critical components, or
- Renew the entire structure

Senior management also has several choices in their bridge replacement strategy, for example:

- Reduce maximum carload weights,
- Prioritize routes for improvement and focus traffic on fewer lines,
- Lengthen average renewal cycles,
- Use less costly bridge materials such as wood in place of steel,
- Increase expense budgets for bridge gangs to do more repairs, and/or
- Increase capital expenditures for bridge renewals.

Only some of these choices involve capital expenditures. Because marginal cost is forward looking, all viable alternatives that equally satisfy the market demand should have the same intrinsic economic properties with respect to their incremental characteristics. The only question is whether the alternative chosen is the most efficient one.

As Friedman (1976, 122) explained, at any given output, there exist any number of marginal cost curves that are steeper than the long-run marginal cost curve. "It follows that at outputs greater than x_o, long run marginal cost must be less than or equal to the short-run marginal cost… It follows that at outputs less than x_o, long run marginal cost must be greater than or equal to the short-run marginal cost shown by any marginal cost curve corresponding to output x_o." It also follows that all of the cost curves associated with each alternative are marginal cost curves. An engineering decision that provides resources more efficiently only affects along which marginal cost curve the firm chooses to operate. If a factor is provided to support a firm's output, the incremental nature of that factor is indifferent to its categorization as an expense or as an investment. Only the rate of change of the cost curve with respect to output is altered.

Fundamentally, the engineering decision (related to how best to provide a resource), *ceteris paribus,* does not affect whether the related factor is fixed or incremental with output. Stated in another way, the engineering decision only affects along which marginal cost curve the firm will operate. Only a business decision can change a variable factor into a fixed cost.

If the B&B Manager makes repairs more frequently due to additional traffic, the maintenance cost is clearly incremental. If it is less expensive to rebuild the bridge, the capital expenditure is therefore also an incremental cost related to incremental output.

5.7 Efficient Resource Allocation

In the view of economists, pricing is a tool for optimal resource allocation (Gomez-Ibanez 1999). Charging transport users their marginal cost (at minimum) ensures that they will make an extra trip or shipment only when the value to them of doing so is at least as great as the cost of providing it.

One way to interpret the results of this research is that railroads, by not fully charging for the incremental cost of capital expenditures, have not been efficiently or optimally allocating these resources. Underestimating this portion of marginal cost will lead to more demand for the under-priced resource than would otherwise occur.

5.8 The Public Policy Question

As the American Association of State Highway and Transportation Officials (AASHTO) (2002) stated, if railroads decide to minimize capital costs, the additional costs to the economy would be on the order of $400-$800 billion. AASHTO's study recommends various schemes for encouraging rail investment, including direct funding from rail revenues, rail user fees or surcharges, federal appropriations, congestion mitigation grants, loans to railroads, and relieving railroads from property taxes. None of the recommendations included the use of a marginal cost framework for pricing highway infrastructure.

By framing the capacity issue in this way, AASHTO missed the fundamental point of why rail capacity may be constrained. Capacity flows from investment, and investment flows from a competitive return on that investment. Constraints in rail capacity and investment can only be resolved if prices rise to the level where ROIC can attract additional capital.

If railroads fully include marginal investment costs in marginal price levels as suggested by this thesis, the result will be twofold. First, railroads will improve their ability to earn a competitive rate of return on investment, attracting more investment in capacity. Second, there will also be a shift in the demand equilibrium from rail to highway (Figure 5.1).

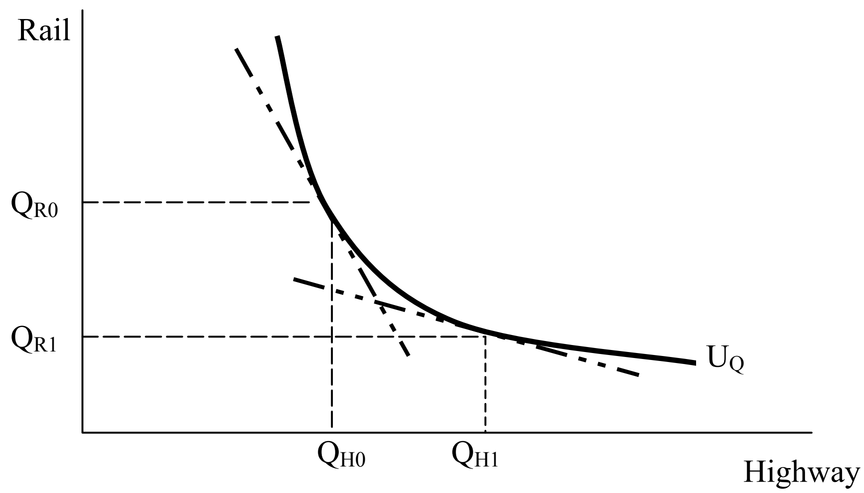

Figure 5.1: Substitution effect of an increase in rail price

In other words, if the cost of rail transportation rises with respect to the cost of highway (and/or waterway) transportation, demand will also shift (from Q_{R0} to Q_{R1} and from Q_{H0} to Q_{H1}) along the transportation utility curve (U_Q) for goods where these modes can be substituted for rail transportation.

If a competing mode charges a price that is no less than the marginal cost of providing the service, such a demand shift could represent an efficient re-allocation of total resources used to provide transportation. But this is not the case. According to congressional testimony, rail competitive heavy trucks pay only 50 percent of their cost responsibility, and the barge industry pays only 15 percent its cost responsibility (U.S. Congress Senate Committee 1987). As a result, a demand shift resulting from an increase in railroad prices will cause escalating public subsidies and rising economic inefficiencies (Figure 5.2).

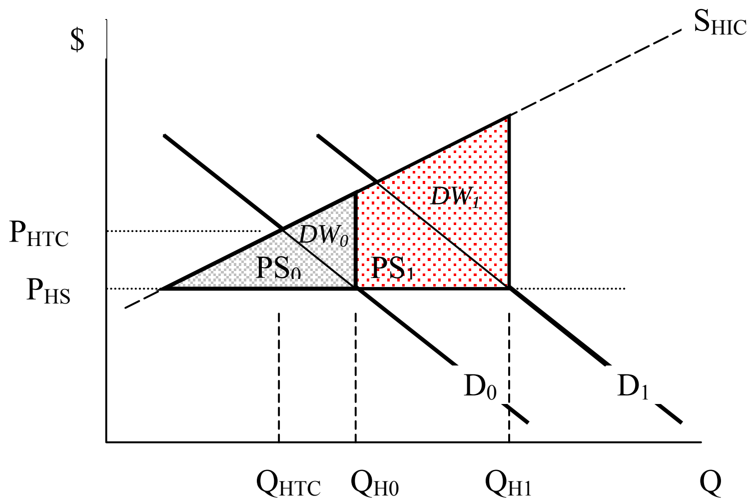

Figure 5.2: Public subsidy needs and dead-weight losses resulting from increased demand for highway infrastructure

Let S_{HIC} represent the internal marginal cost (maintenance, operation, and investment) curve for highway infrastructure. D_0 represents the initial demand curve for highway infrastructure. P_{HTC} is the price (for infrastructure) that recovers all internal marginal costs. P_{HS} is the actual price charged under subsidy, which is less than P_{HTC}. Initially, the public subsidy required is PS_0, the area bounded by P_{HS}, S_{HIC}, and Q_{H0}. The net efficiency loss ("dead-weight loss" as defined by economists) is DW_0, the area bounded by Q_{H0}, S_{HIC}, and D_0.

Now suppose that, as a result of the substitution effect, the highway demand curve shifts from D_0 to D_1. The public subsidy increases to PS_1, the area bounded by P_{HS}, S_{HIC}, and Q_{H1}. The net efficiency loss increases from DW_0 to DW_1, the area bounded by Q_{H1}, S_{HIC}, and D_1.

The increase in public subsidy and economic (or efficiency) losses depends not only on the actual shape of the demand and supply curves, but also on the price differential created by the subsidy (P_{HTC}/P_{HS}). The greater the price subsidy, the larger the effect on public funding requirements and economic losses that result from the substitution highway effect.

This effect is even more substantial when external costs are considered, for example, traffic congestion, accidents and pollution from added truck traffic (Figure 5.3).

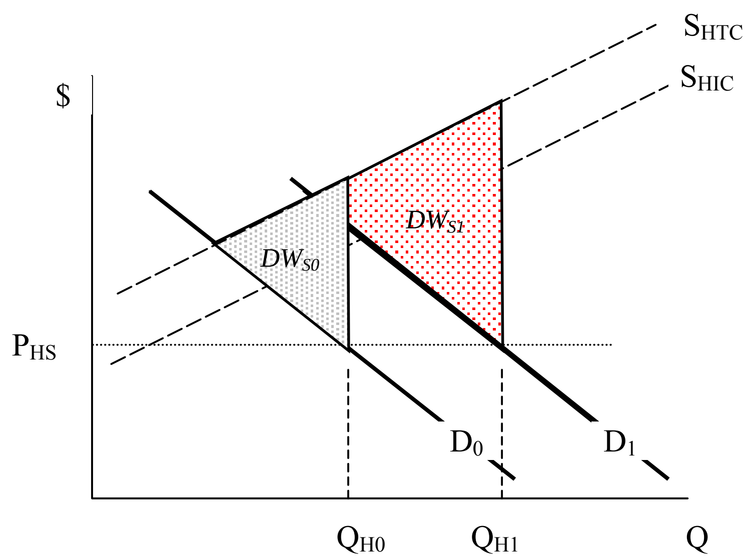

Figure 5.3: Dead-weight loss (with external social costs) resulting from increased demand for highway infrastructure

Let S_{HTSC} represent the total external and internal marginal costs of added truck traffic. DW_{S0} represents the initial dead-weight loss (bounded by S_{HTC}, Q_{H0}, and D_0) and DW_{S1} represents the after-substitution dead-weight loss (bounded by S_{HTC}, Q_{H1}, and D_1). The net welfare loss, including the external costs, increases from DW_{S0} to DW_{S1}, and represents an even greater loss of efficiency than just the direct or internal costs. In other words, $(DW_{S1} - DW_{S0}) > (DW_1 - DW_0)$.

Figures 5.1, 5.2 and 5.3 are over-simplified versions of the real world situation where highway infrastructure supply is constrained and additional external costs increase at an exponential rate as demand approaches capacity. However, they are illustrative of the effect that an increase in rail prices will have on demand, public subsidy, and direct and total social costs attributable to highway transportation, *ceteris paribus*.

The result of that shift, while more efficient for rail investors, is substantially greater cost for the public, perhaps on the scale that AASHTO describes. Contrary to the implications in the AASHTO report, these escalating costs occur not because of an inadequate supply of railroad infrastructure, but from subsidies provided to highway and waterway users.

The public policy question is whether, as a result of an increase in railroad prices to recover variable capital costs, there will be an inefficient equilibrium shift to highway (and waterway) transportation, or whether public policy makers will choose to price highway (and waterway) infrastructure more closely in line with marginal cost.

5.9 Maximizing Earnings v. Returns to Investment

The findings of Chapter 4 lead to the conclusion that a firm with large variable investment can maximize earnings (net income) or returns to invested capital (free cash flow), but not both. This can be demonstrated using economic theory and an example.

Recall equations (4.2) and (4.3) from Chapter 4 as shown below:

$$NI = TR - E_V - E_F \tag{4.2}$$

$$FCF = TR - E_V - I_V - E_F - I_F \tag{4.3}$$

Profit maximization requires that the first derivative of each equation with respect to output is equal to zero (assuming the second derivative is negative to establish a maximum or a concave down function) as follows:

$$dNI/dQ = (P-E_V) = 0$$

$$dFCF/dQ = (P-E_V-I_V) = 0$$

By definition, if I_V is not equal to zero, then:

$$(P-E_V) \neq (P-E_V-I_V)$$

thus,

$$dNI/dQ \neq dFCF/dQ$$

As long as I_V is substantially greater than zero, the profit maximization functions are not equal. This means that firms with substantial variable investment cannot maximize net income and free cash flow at the same time.

This proof is, however, only appropriate for instantaneous or short term pricing calculations. Over the long run, investment is depreciable and capital expenditures flow to the income sheet in the form of depreciation expense. But this requires consideration of the time dimension in terms of investment life (asset life) and investor behavior.

Asset life affects the period over which investments are depreciated and expensed in the income statement. The shorter the (average) asset life, the more closely net income and free cash flow are related. With longer (average) asset lives (as in the railroad industry where asset life may average 20 years or more), the less closely related these are. In an inflationary environment, capital expenditures may continue to exceed depreciation expense, as has been the case with railroads over the past 25 years. The firm will be able to increase capital expenditures as long as it is still able to generate positive free cash flow. (This assumes that debt loads are relatively constant. In the short run, a firm can increase investment without positive cash flow if it uses debt to fund increasing levels of investment, but eventually this results in greater interest expense that reduces net income.)

Investor behavior must also be considered. If the firm continually earns less than its cost of capital, investors will constrain capital expenditures to the point when, eventually, depreciation expense exceeds capital expenditures. But this occurs only if investors respond in this manner. If the firm is able to earn a return on investment that exceeds the cost of capital, investors may not require reductions in capital expenditures. Even if the firm does not maximize return on investment, it may be able to earn a capital surplus (a positive ROIC minus CoC), and investors may be satisfied even though economic profits are not maximized.

Suppose that railroads were able to increase prices as a result of relatively inelastic demand for certain goods such as coal, grain or chemicals for which there are relatively few substitutes. Revenues may rise to the point at which ROIC equals or exceeds CoC, and the capital deficit declines or becomes positive. In fact, over the past several years, the industry's capital deficit has been declining. But this may result from rising profits on some traffic (coal, grain, chemicals) even when prices for other goods (intermodal) may not recover the full marginal cost of investment. The relative mix of goods is an important factor, but as long as the net excess profit (profits over and above the cost of capital) on some goods exceeds the net economic loss incurred on other goods, then total return on investment will exceed the overall cost of capital. This is not cross-subsidization of one commodity to another; it is sub-optimization of return on investment (the subsidization of at least some shippers by investors). Investors may be satisfied with improving economic profits, even if the true profit (ROIC) potential is not optimized.

5.10 The Executive's Dilemma

This research suggests that firms with high variable investment can use pricing strategies that either maximize earnings (net income) or returns to invested capital (free cash flow), but not both. Excluding variable investment costs in marginal costs and pricing decisions will tend to attract some marginal products and services that would increase earnings, even though the additional investment costs would more than offset the additional earnings. From an economic standpoint, the strategy of the firm should be to maximize returns to investment. But this is a more complex issue in the real world of the stock market.

The problem, to some degree, is a matter of how investors and investment managers measure a firm's performance and decide whether to make "buy, hold, or sell" decisions regarding a particular stock. Investors generally use earnings as the nominal measure of performance, but this is made with the expectation that net income is reflective of the firm's potential to produce cash flow (Brigham and Houston 1999, 23). As a result, near-term stock performance normally follows earning performance. The market’s signal to railroad executives is therefore a focus on improved earnings, not returns to invested capital.

In the long run, if the return on invested capital (ROIC) does not follow earnings, investors may eventually become skeptical about the stock’s real value. Indeed, a growing number of investment analysts rely on cash flow to assess performance (Brigham and Houston 1999, 23). Because railroads have high variable investment requirements, railroad executives must decide whether to maximize stock values by maximizing earnings or by maximizing returns to investment. From an economic viewpoint, ROIC is what matters most, but the guidance of the marketplace may not consistently reflect this viewpoint.

6.0 Future Research

In my review of the financial literature I did not find analyses or studies regarding the concept that investment cash flows, whether for capital expenditures, working capital, or other forms of ongoing investment, should be considered in the estimation of marginal cost and therefore included in fundamental pricing criteria. As a result, the concepts and methods developed in this research appear to have implications beyond the railroad industry. In any situation where investment cash flows are related to incremental changes in output, such flows should be considered in marginal cost calculations and therefore pricing decisions. This concept does not appear in financial or cost accounting literature. If true, the suggestion that railroads have mis-applied modern financial theory or consciously failed to optimize ROIC is incorrect. My experience indicates that railroads have worked strenuously to improve earnings and return on invested capital. But because railroads require large ongoing capital expenditures, the absence of a theory that incorporates such expenditures into marginal costs appears to have contributed to sub-optimal returns to investment.

The correct allocation of investment cash flows to specific goods and services may be more difficult than it appears at first glance. Capital expenditures may appear lumpier at the product line level in comparison to the firm level. Some benefits are indirect, for example when improvements made on one route reduce congestion costs on a parallel route. In such instances, research is needed to develop a method that correctly allocates such incremental investments to products and services that benefit from such investments.

Other industries that have large variable capital expenditures may also sub-optimize returns to invested capital as a result of not including variable capital expenditures in marginal cost estimates. The methods employed in this analysis are not necessarily specific to railroads even though estimates of certain factors, such as fixed costs, are derived from railroad-specific studies.

In other commercial settings, for example rapidly growing enterprises, this research may be beneficially applied to variable working capital. Pricing decisions for products or services that require incremental growth in working capital, either because of inventory requirements or net receivables (payables minus receivables), should incorporate these costs in the marginal cost calculation for goods and services.

Finally, in the process of conducting this research, certain insights were developed into the theoretical mathematical relationships between changes in firm value, free cash flow, and investment. As described in chapter 3, the data suggest that, in the railroad industry, changes in free cash flow are related to changes in capital expenditures. This raises the question: what is the relationship between firm value and free cash flow with respect to changes in investment? Specifically, what is the relationship between changes in free cash flow with respect to investment ($dFCF_{CE}/dI$) and firm value with respect to investment (dFV/dI)?

Each of these research issues is addressed below.

6.1 Allocation of Variable Capital Expenditures to Particular Traffic Segments

If capital expenditures are incremental costs, how should the analyst allocate such costs to particular shipments? Suppose a series of siding extensions is scheduled on one of two parallel routes to relieve congestion on a simple network. Should the prospective capital expenditures be allocated strictly to traffic operating over the route with the improvements? While traffic on this route clearly benefits from the additional capacity, traffic operating over the parallel route may also benefit from the capacity improvements if congestion is reduced on both routes as a result of the improvement.

The allocation of variable capital expenditures to specific traffic movements should be based upon more than simple usage criteria. When network improvements from capital expenditures extend beyond the specific route in question, these costs should be allocated to all traffic that benefits, directly or indirectly, from the prospective investments. Methods to allocate such capital expenditures to particular traffic movements need to be developed using economic and transportation engineering criteria that consider benefits to other parts of the network.

6.2 Recovering Variable Capital Expenditures in Other Industries

Additional research is also needed to determine if, and to what degree, other industries may not include incremental investment costs in marginal analysis, in particular those with high levels of capital spending.

In chapter 4, I noted that a failure to include variable capital expenditures in marginal costs (price floors) could be detected by comparing relative trends in net income and free cash flow. Specifically, if (1) the relationship between net income and output is positive, (2) the relationship between free cash flow and output is negative, and (3) investment expenditures are principally related to current or near term output, then the firm is incurring economic losses by not considering investment expenditures in marginal cost estimates. My review of financial literature did not reveal any research on the role of ongoing investment in marginal cost analysis, nor did it uncover any current research on the implications of inverse relationships of net income and free cash flow with respect to output. As a result, the role of capital expenditures in marginal analysis may not be clearly understood on a broader scale than just this application to the railroad industry. Although certain estimates (fixed expenses, recovery of fixed expense, cost of capital) were based on railroad specific studies, the general methodology presented is not restricted to this industry.

6.3 Recovering Variable Working Capital and Other Investments

The analysis presented in chapter 4 initially estimated the degree to which variable investment was reflected in marginal prices, and then narrowed this definition of variable investment (I_V) to variable capital expenditures (CE_V). In some industries, working capital (inventories, accounts payable and receivables) may be the predominant form of variable investment. In such instances, research may be directed to estimate the degree to which working capital is reflected in marginal cost estimates. In other words, this general approach may be used to determine if sub-optimal pricing and returns to invested capital are occurring as a result of a failure to sufficiently include working capital in marginal costs and marginal prices.

Using the broad definition of investment presented in Chapter 4, investment costs can be defined as:

$$I = CE + WC + OI$$

where:

- I = Ongoing annual investment
- CE = Capital expenditures
- WC = Changes in working capital
- OI = Changes in other investments

Similarly, variable investment can be defined as:

$$I_V = CE_V + WC_V + OI_V$$

where:

- I_V = Variable ongoing annual investment
- CE_V = Variable capital expenditures
- WC_V = Variable working capital
- OI_V = Variable other ongoing investments

In chapter 4, I narrowed the definition of free cash flow (FCF) to free cash flow with respect to capital expenditures (FCF_{CE}) by considering only net income, capital expenditures and depreciation. A similar approach may be used to calculate free cash flow with respect to working capital (FCF_{WC}) by considering only net income and changes in working capital. Likewise, this approach may be used to calculate free cash flow with respect to other investments (FCF_{OI}) by considering only net income, deferred income taxes, property sales and purchases, and other investments. The result is that variable working capital and variable other investments may be estimated using the method provided in chapter 4, modified as shown below.

$$dNI/dQ - dFCF_{WC} = WC_V$$

$$dNI/dQ - dFCF_{OI} = OI_V$$

where:

FCF_{WC} = Free cash flow with respect to working capital

FCF_{OI} = Free cash flow with respect to other investments

WC_V = Variable working capital

OI_V = Variable other investments

The price component for recovery of variable working capital and variable other expenditures may be estimated using the procedures described in chapter 4. As stated previously, this general approach may be used to determine if sub-optimal pricing and returns to invested capital are occurring as a result of a failure to sufficiently include working capital or other investments in marginal costs and marginal prices.

6.4 Firm Value and Investment

I found that the relationship between firm value and investment (capital expenditures, working capital, and other ongoing investments) was a function of the relationship between free cash flow and investment. If investment is related to current and near term growth, then:

$$dFV/dI = f(dFCF/dI) \tag{6.1}$$

This can be demonstrated as follows. Beginning with a basic computation of the value of a firm being the net present value of all free cash flows generated by the firm plus a terminal growth factor:

$$FV = \sum_0^t FCF_t\left(\frac{1}{1+i}\right)^{-t} + FCF_{t+1}\left(\frac{1}{1+i}\right)^{-t}\left(\frac{1}{K_w - g}\right) \tag{6.2}$$

where:

i = interest rate

K_w = Cost of Capital

g = long-run growth rate

Assume continuity and a growth rate equal to dFCF/dI. Differentiating each side of equation (6.2) with respect to investment spending results in equation (6.3):

$$\frac{dFV}{dI}=\frac{dFCF_{1\to t}}{dI}\left(\frac{1}{1+i}\right)^{-t}+\frac{dFCF_{t+1}}{dI}\left(\frac{1}{1+i}\right)^{-t}\left(\frac{1}{K_w-\frac{dFCF_t}{dI}}\right)+FCF_{t+1}\left(\frac{1}{1+i}\right)^{-t}\left(\frac{1}{K_w-\frac{d^2FCF_t}{dI^2}}\right) \quad (6.3)$$

At the limit, as the time period goes to zero, i → 0 and FCF → 0; and equation (6.3) simplifies to equation (6.4):

$$\frac{dFV}{dI}=\frac{dFCF_{1\to t}}{dI}+\frac{dFCF_{t+1}}{dI}\left(\frac{1}{K_w-\frac{dFCF_t}{dI}}\right) \quad (6.4)$$

Assuming that future and current changes in FCF (w.r.t. investment spending) are equal to historic changes in FCF, equation (6.4) simplifies to equation (6.5):

$$\frac{dFV}{dI}=\frac{dFCF}{dI}\left(1+\left(\frac{1}{K_w-\frac{dFCF}{dI}}\right)\right) \quad (6.5)$$

If dFCF/dI is negative, then dFV/dI will also be negative if investment expenditures are made principally for short run growth as shown in Figure 6.1. Similarly, if dFCF/dI is positive, then dFV/dI will also be positive.

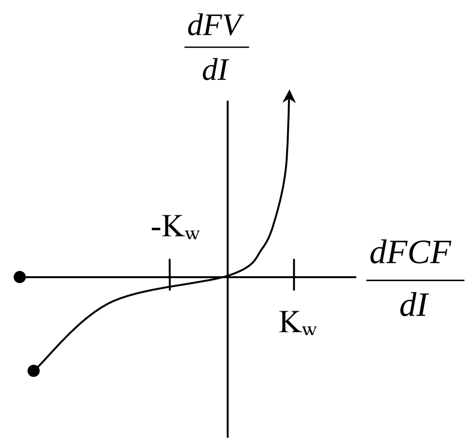

Figure 6.1: Relationship of dFV/dI, dFCF/dI, and K_w

Additional research into financial trends and changes in stock value could explore this relationship, and could prove useful in predicting the long-run value of firms and/or industries with significant investment in the form of either capital expenditures, working capital, or other forms of investment.

Depending on the nature of the firm and the variable nature of the investments it makes, one or more of the investment categories may be considered in equation (6.1). A more general form of equation (6.1) may be written as shown in equation (6.6):

$$dFV/d(CE + WC + OI) = f\{dFCF/d(CE + WC + OI)\} \qquad (6.6)$$

Accordingly, equation (6.5) may be derived with respect to capital expenditures, working capital, or other ongoing investments, or a combination of these. Because working capital changes are clearly related to short run firm growth, equation (6.7) may be of particular significance to firms with rapid growth in working capital requirements.

$$dFV/dWC = f(dFCF/dWC) \quad (6.7)$$

In other words, as illustrated in Figure (6.1), if the relationship between free cash flow and working capital (i.e., dFCF/dWC) is negative, then firm value is declining if working capital requirements are growing. This version (6.7) of equation (6.6) may have potential for application in instances where incremental working capital is of more concern than incremental capital expenditures.

7.0 Literature Survey

This survey is presented in chronological sequence and includes a wide variety of sources. As such, the material tends to jump from subject to subject with little transition. The information supplied herein provides a broad basis for the research presented in the preceding chapters. To assist the reader in keeping track of new and previous sources, when a new source is cited, it is emphasized with bold type. When the source is referred to in a later section, it is underlined.

Ellet, an American railroad engineer, supported the need for long- and short-haul discrimination (1839). "For that class of commodities for which there are other lines in competition, and which can sustain the charge of carriage to either, the difficulty of reaching the rival will increase, as we proceed along the improvement; and, consequently, the tax which we may impose on the trade will likewise increase." In a broad sense, the demand for transportation is determined by the elasticity of demand for the final output and by the number of substitutes for the good transported.

Dupuit established the importance of distinguishing variable and fixed costs in the earliest days of railway construction (**Ekelund & Hebert** 1999, 135-136). "… it is the nature of all production that it can be broken down into fixed costs and variable. Now, for certain products the fixed costs constitute almost the entire expense, and it becomes problematic whether these costs can be adequately covered by earnings." Dupuit was the first to fully develop the theory of utility as a separate concept from value. "Utility and value are two different properties not independent, but having between them a conjoined relationship in which enters another circumstance, which is rarity." Dupuit recognized that railroad rates had to cover short-run average variable costs in order for the railroad to take traffic, and recognized that all costs had to be covered in the long-run. "Interest charges would be marginal costs if the construction of the bridge were at issue."

"Regarding what we now call first-degree discrimination, for example, Dupuit argued that charging maximum demand price for each unit of the commodity should be the foremost principle of rational price policy. In order to extend the use of certain transport services … impose on each traveler, and on each merchandise, a price only slightly less than the one that would prevent them from using the road" (Ibid, 199). "The full social value of the entire system is maximized through this process (pricing based on differences in demand elasticities), and the returns provide an investment criterion" (Ibid, 204).

Dupuit's suggestion was formalized in a paper by **David Freidman** who demonstrated that such "discriminations" are absolutely necessary in order to arrive at investment criteria that maximize social gain (Freidman 1979). Dupuit's support for long- and short-haul discrimination was that competition was far more likely on a long haul than on a short haul (Ekelund and Hebert 1999, 214). He helped provide the scientific rationale that government pricing regulation suppressed profits, drove some railroads out of business and reduced efficient investment in the overall transport system (Ibid, 239).

Edgeworth (1910) considered Dupuit "the earliest, and still … the highest authority on the theory of price discrimination."

Ekelund and Hebert (1983, 270) discussed Dupuit's general rule for marginal cost that included a capital cost component. They described how Dupuit's background as an engineer gave him a particular understanding of the concept of marginal cost and marginal utility because he was "… cut from the cloth of the engineer rather than the cloth of the philosopher" (Ibid, 272). Dupuit defined marginal cost as the change in *total cost* with respect to output. "The marginal cost is the change in total costs as output is increased. … Marginal cost must equal average variable costs and average total costs then the latter are at a minimum."

Lardner (1850, 194) published a treatise on railway processes and costs and identified the need to distinguish between retrospective and prospective costs. "An analysis of the past expenses of a railway may have two objects – retrospective and prospective. Considered retrospectively, its purposes can only be the adjustment of accounts, an object which has no relation to our present purpose. Considered prospectively, such an analysis has the most important purposes. 1st. It supplies the grounds of an estimate of future expenses. 2nd. It supplies the basis of a future tariff. …. The analysis required for the second purpose above mentioned, to supply the basis of a tariff, must be one of a much more elaborate and a very different sort. For this purpose it will not be sufficient to be informed of the gross sums expended under the usual heads of expenditure, such as direction and management, of way and works, locomotive power &c. It will be necessary to ascertain, with some degree of precision, the expense which has attended in past years the transport of each class of traffic, such expenses being obviously the first condition upon which a tariff can be based." Lardner was a British engineer and a champion of the new theory of demand developed by Dupuit and Cournot.

On classification of MOW costs, Lardner stated: "The expenses of the maintenance of the way and works consist of two parts, distinct from each other, and depending on different cases. 1st. Those which are appropriated to the repair of the wear and damage produced by time…. 2nd. Those which are appropriated to the repairs of the wear and damage produced by actions of the rolling stock and the traffic upon the road. … The repairs .. produced by time and weather .. includes the slopes, of cuttings of embankments, of the substructure of the road, consisting of ballasting and drains, of the renewal of sleepers, the repairs of bridges, tunnels, and viaducts, gates and fences, and in a word, of all of the appendages and accessories of the road. Altogether independent of time and weather and depending exclusively on the traffic, includes the iron work of the road, comprising the rails, chairs, and fastenings" (Ibid, 204-5). Lardner presented an explanation of a method to maximize profits in recognition of the elasticity of demand to price.

Hughitt stated that inferior construction was more expensive than better initial construction, and described the practice of charging construction costs to operating expenses (Kirkman 1880, 83, 134).

Wellington (1888, 109-11) believed that the majority of operating expenses was independent of the amount of traffic. He estimated that only 33.4 percent of total expenses were variable with traffic. However, this statement was later qualified. "Yet it must be admitted that there are some strange anomalies in the records of maintenance of way expenses which seem to indicate that such expenses will continue to bear a nearly constant ratio to the train expenses" (Ibid, 127). Wellington described the changes in railway plant that accompanied rapid growth of traffic at that time (1877-1887), including the introduction of steel rail, the use of first class ballast, and the creosoting of cross-ties.

Wellington attributed the ability of carriers to reduce their costs per gross-ton-mile to new locomotive power and expansion of plant.

Taussig (1891) provided early insight on the concept that rates were related to elasticity of demand. "Traffic, which will continue to come, even at comparatively high rates, will continue to be taxed high, and will contribute largely to fixed charges. … traffic for which the demand is sensitive to price, and which can be got only at low rates, will contribute little." He argued that rail costs were preponderantly *joint*, which supported a *necessary* or *all or nothing* case for price discrimination as a foundation for railroad viability.

Kirkman (1892, 281-293) described early ways of accounting for construction costs and the difficulty of separating operating expenses and capital investment. "Many weak companies have made it a practice to systematically include the cost of additions and improvements under the head of operating. … If the property should ever be able to earn a return on its full cost, it will quite likely be prevented from do so, because of the difficulty of making the cost appear. … In many cases, the accountant can not separate that which comes under such head (property) from that which comes under the head of operating. … In the early days of railroads, no attempt was made to properly classify construction expenses…. Still another influence has operated to lessen the apparent cost of railroads. … Another obstacle in the way of accurate accounting is the opening of new roads before they are fairly completed. Construction and operating expenses, in such cases, mingled in one indistinguishable mass. … Of all accounts, the construction account is the most difficult to keep. Only those familiar with such matters know how difficult it is to separate construction from ordinary working expenses. … Many items entering into cost of construction are so mixed up with operating expenses that they can only be approximated."

Hadley (1886, 144-45) of Yale University argued that regulation of railroads or other related industries was totally unnecessary and, in the long run, disastrous for the welfare of society. "A commission with judicial powers is almost certain to magnify its own office. This danger made itself strongly felt in England … The United States Commission might decide a few cases; but its authority would be evaded in a hundred times as many more. The worst evil which could possibly befall us, would be the attempt to apply a great deal of regulation somewhere, by an agency which was not strong enough to enforce such regulation everywhere." Hadley (1895, 262) believed that the expense of handling each additional carload varied considerably, including a moderate share of track maintenance and general expenses. He also described why discriminatory local rates were necessary if communities were to have access to railroads (Ibid, 115). Standing alone among railway economics practitioners of his time and grounded in the principles set forth by Ellet, Dupuit, and Lardner, Hadley opposed the Act to Regulate Commerce and the Interstate Commerce Commission (Ekelund and Hebert 1999, 233). "For Dupuit (and later Hadley), monopoly is never 'absolute'. To tamper with the pricing structure of firms said to have some degree of monopoly power is to disturb the ability of a market system to respond competitively — that is, with respect to the opportunity costs of transport — and to slow long-term adjustments toward lower and more competitive prices for transport" (Ibid, 235).

Newcomb (1898), Chief of the Section of Freight Rates in the Division of Statistics of the USDA and Instructor in Statistics and Transportation at Columbian University, mentioned the variable nature of railway maintenance. He found an 18.5% reduction in the number of MOW employees per mile of track from 1893 to 1884 as a result of a 16.5% decrease in ton miles.

Talcott (1904, 56-58) believed that it was possible to double traffic and incur only a 25 to 45% increase in freight cost. He did not include interest on capital as a variable expense, seeing it as a cost which, only in the long run, was affected by traffic volume. "Transportation is the product of a railway, and interest on the capital invested in the business is not only a part of the cost of transportation, but is an obtrusive element of cost, for the reason that railways are largely, if not exclusively, built with borrowed capital, evidenced by securities, the holders of which want their interest with great regularity, and failing to get it are prompt to inaugurate foreclosure proceedings."

Pratt (1905, 27-28) discussed how rate legislation in Britain worked against the interest of rail customers. "… railway companies now have to be exceedingly careful before they reduce any particular rate — even when they could afford to do so — because of the difficulties they would encounter if circumstances might require them to raise it again to its original level. In other words, legislation intended to safeguard the interests of traders has deprived railway rates to a considerable degree of that element of elasticity from which, had the purely commercial relations of railways and traders been less hampered, advantages much more practical than those secured under actual conditions might have been gained."

Acworth (1905, 55) believed that half of expenses were fixed and half variable with traffic, and that MOW costs were almost entirely fixed. "Certain expenses — for instance, maintenance of works — hardly increase at all."

Meyer (1905), Professor of Political Economy at University of Chicago, recommended against ICC control of rates, except in cases of unreasonable discrimination. He found discriminatory rates beneficial. "When the Interstate Commerce Commission was created, under the Act To Regulate Commerce, it found in existence in this country a heterogeneous mass of railway rates made with the sole aim of promoting trade, of making two blades of grass row in the place of one. Discrimination — the result of the exercise of discretion — was the keystone of the situation. That discrimination was not the result of caprice; it was the result of meeting with intelligence and courage the needs of trade and industry. The effect of that discrimination was a heterogeneous mass of railway rates that knit the different producing, distributing, and consuming sections of this country into a more compact trading unit than was to be found anywhere else in the world" (Ibid, 457). "It is impossible for the State to conserve and promote public welfare by intervening in the regulation of railway rates, beyond the point of seeking to abolish secret personal discriminations …" (Ibid, 472).

Colson (1907, 25) argued that variable expense associated with maintenance of road were negligible. "Though the maintenance of a road and the expenses of administration undoubtedly vary to a certain extent with traffic, they comprise a sufficiently constant quantity for the variation to be ignored."

Merritt (1906, 16) in his Ph.D. Dissertation of Economics, University of Chicago, concluded that fair return on investment is essential for future investment: "for if investors were to be deprived of the privilege of earning such returns, there would never be another mile of railway built in this country, which in the present state of our economy would be disastrous."

Haney (1908, 210-15), Professor of Economics at University of Iowa, provided a historical view on the subject of railroad rates and return on investment. In the early days it was believed that railway rates would be similarly constructed to those on canals and highways, consisting of two parts: one for the cost of service, another for "toll" being the payment for use of track or "way". Early charters restricted such tolls from exceeding 25 percent per annum of the aggregate amount of constructing and maintaining the railroad. An 1835 charter restricted tolls to 20 percent of the capital invested. Rates for transportation, however, were to be based solely on cost.

Cleveland (1909, 160-61), of the University of Pennsylvania, related the granting of railroad charters and the original structure of rates. "The grant of a charter is an act of sovereignty. … To obtain a charter during the early period of railway promotion, it was only necessary to petition the legislature, setting forth the purpose of the proposed improvement, the public advantage to accrue, and the powers to be exercised. … As the first railways were regarded as improved highways, their charters in many cases conferred the right to collect a toll for the use of the road, and an additional charge for conducting transportation where the equipment of the company was used. Thus the charter of the Boston and Providence gave the right to build a railroad which might be used by any person who would comply with the necessary regulations, and authorized the directors to erect toll houses, establish gates, appoint toll gatherers and demand toll upon the road. A step in advance was taken in the charter of the Maine, New Hampshire, and Massachusetts Railroad, which gave the corporation the privilege of buying cars and locomotives for the transportation of passengers and freight. The Baltimore and Ohio charter, however, although granted as early as 1827, conferred authority over the directors to levy on all goods a mileage charge for toll and one for transportation, and the fact that it preceded many charters which included the clause providing for state operation shows that the form of legal phrasing persisted after the idea of the railroad as an improved form of road had been generally abandoned."

Johnson (1908, 272), Professor of Transportation at the University of Pennsylvania, addressed the problem of confusing expenses and costs. "In discussing the cost theory of railway rates, it is necessary to keep clearly in mind what is meant by cost, because the word is used with several meanings. In the preceding paragraph the word is used to include all the expenses chargeable against the service — interest on the capital employed, deterioration of plant, insurance, wages, outlay for operating expenses, ordinary business profits, etc. The word cost is, however, frequently used to mean only operating expenses or the expenses incurred in using the plant to perform a service." Johnson described the need to cover incremental cost (Ibid, 278). "… a rate for any particular service can hardly be just to the carrier unless it equals or somewhat exceeds the additional costs incurred in performing that service — the expenses that would have been avoided had that service not been rendered." He also stated that investment was needed to improve efficiency and earnings. "As gross earnings rose rapidly from 1890 to 1893, the net income available for dividends rose slowly and actually declined during 1892. The larger earnings were being absorbed by the fixed charges and the operating expenses, especially the latter. It being the practice of American companies to pay for additional equipment, for improvements and new construction largely from earnings, as well by the sale of bonds and stocks, a portion of the earnings received in prosperous times is used for betterments and extensions. What occurred during the three years prior to 1893 has taken place on a much larger scale since 1897. The influence of the bondholder is greater than that of the stockholder in shaping the finances and management of American railways, and present profits of the stockholder are restricted in order to strengthen the future earning capacity and value of the property. That is, on the whole, fortunate, because this policy is bringing about constant improvements in our railroad system, and giving a better and more economical service" (Ibid, 104-5).

Hammond (1911, 43), Professor of Economics, Ohio State University, stated that the ICC had difficulty with assigning exact cost. "The members of the Commission have, of course, never pretended that they could ascertain the exact proportion of the fixed and operating expenses assignable to a given commodity. … Each commodity transported should, as far as possible, be made to defray its own share not only of operating and terminal costs but also of the fixed costs and dividends" (Ibid, 193).

Ripley (1912, 51-52), Professor of Economics, Harvard University, discussed fixed and variable maintenance expenses and estimated that 5 to 10% should be considered variable with "number or size of passing trains." He described a 1907 rate case in which it was ruled that 100% of rail costs, 33% of ties costs, and 10% of all other expenditures are related to volume. He stated that 44.6 of operating expenses are variable, with one-third of MOW expenses as variable and noted the relationship to capacity. "… the cost of operation tends to decline until a condition of congestion of the existing plant is reached …" He presented evidence from a UK railway in which only one-third of the maintenance expenses were considered variable.

Dunn (1912, 7-8) stated that MOW expenses increase less proportionately than increases in traffic, but he also qualified this as applicable to "a railway which is not working to its full capacity …" Dunn also described the advantages of discriminatory rates. "The main difference [between U.S. and foreign railways] has been that in many foreign countries more consideration has been given to the cost of the service as compared with the value of the service — in other words to the average cost of the service as distinguished from the additional cost; and to this the greater density of freight traffic that has been developed here, and the lower average rate at which it is handled, are largely due" (Ibid, 11-12).

Knoop (1913, 77-79) suggested that two thirds of MOW costs are variable with traffic and one third fixed based on the experience of the Pennsylvania Railroad (USA) and Midland Railroad (UK).

Sakolski (1913, 4-5), New York University School of Commerce, Accounts, and Finance, illuminated the debate regarding different methods of accounting for additions and renewal. "In its classification of additions and betterments, the Commission directed a blow against the creation of hidden assets by the railroads and the concealment of profits through inflation of current operating expenses. A number of American railroads had gone beyond the recognized principle of charging operating expenses with only the cost of such improvements and betterments as do not produce revenue. By charging productive improvements to operation, they have actually increased their capital assets through current income without having a permanent record thereof on their books. The continuation of this practice under the ICC's control would seriously impair the value of railroad accounts as a gauge of actual operating costs. The Commission, therefore, in distinguishing between expenditures 'chargeable to capital' and expenditures 'chargeable to income' applied a rigid rule for all railroads regardless of their varying traffic conditions and financial policies. … In rail replacements, for example, the Commission has ordered that when heavier rails than those replaced are put down, the difference in cost arising from additional weight is capital expense and must not be charged against operating expenses. … Many experienced railroad officers, however, claim that in all such cases operating expenses should be charged with the full amount necessary to preserve earning efficiency. They point out that by reason of the larger, heavier, more frequent … traffic … it is vitally necessary to charge to operating expenses all extra charges required to preserve the railroad in the same general earning status as it was before. In other words, since railroad facilities are constantly improved and increased to preserve earning capacity the necessary expenses for doing this must be met in part at least from revenue." Sakolski also described how traffic density affects unit cost. "The more business is done, the lower the cost of performing each unit or item of business. … Accordingly, to base rates entirely on the cost would be attempting to find one unknown quantity by using another" (Ibid, 177-79).

Lorenz (1915), Director of the ICC Bureau of Statistics, studied sixty-six large railroad companies and stated, "… if operating expenses per gross ton mile be plotted along a vertical axis, and density (gross ton miles per mile of line) be plotted along the horizontal axis, and the roads be located on a chart thus constructed. The curve which indicates the relation descends rapidly at first and then gently." He found that capital investment increased with traffic density. Lorenz conducted statistical studies correlating traffic density with the ICC valuations of various railroads. He related Maintenance of Way and Structures expenditures with gross ton mile density for different railroads.

Ripley (1915, 75-79) stated that the net return on railroad capitalization average 6% in the U.S. and ranged from 3% on the Chicago Great Western to 10% on the Union Pacific.

Brown (1916, 13-23), Professor of Economics, University of Missouri, discussed the relationship of capital costs to operating costs. "However large are the yearly expenses of a (rail) road, i.e., the expenses of doing, the expenses of becoming overshadows these. The predominant fact in a railroad company's history is building the road, and the existence and relative magnitude of this primary cost has large significance in the problem of rate making. It is commonly stated that the railroad business is subject to a law of decreasing cost, or, as it is sometimes expressed, of increasing returns.

Taking expenses as a whole, they do not increase in proportion to business. But it should be emphasized that the tendency to decreasing proportionate cost with increasing traffic applies, in its full extent, only up to the point where the railroad plant is most economically utilized. … After that point is reached, greater business may require the construction and of maintenance of a larger plant than before. … But it should be emphasized that if the total traffic of a railroad does not pay the necessary general expenses, and if it is not expected to do so in the future, business will stop and the road will be abandoned; or such general expenses as repairs may cease temporarily to be met, and the road will finally be abandoned which it can no longer be used without its owners meeting these expenses. … Social economy does not require that each train load of freight should pay just as much as towards general expenses as every other train load. … It is not enough to say that a railroad should not be constructed unless it will yield an average profit on its labor cost. It should yield, also, a surplus above this amount, as great as the land space required would yield in the best alternative use."

Peabody (1916, 108-12), statistician at the ATSF railroad, provided a detailed account of the organization of railroad management and maintenance, in particular the use of floating and section gangs. "Section Gang: This force is in charge of a section foreman and consists of from two to ten men, who maintain from five to seven miles of main track with the appurtenant sidings and tracks. At certain periods these forces are increased materially for extraordinary work, as during the times of tie-replacement and rail-renewal, and in special work outside the ordinary routine. Stated generally, this force lines and surfaces track, replaces and tamps ties, cleans ditches, cuts and burs weeds, and repairs fences, road crossings, and other track structures. The policing of the track is one of the important duties of the section force. Some member of the force is designated as a 'trackwalker' whose duty it is to inspect each rail and joint as he walks over the track, in doing which he tightens all bolts in the joints and note all low joints and defects at switches for the purpose of reporting to the foreman. … In addition, many roads work what are called 'floating gangs,' who live in the boarding cars of the company and are used over the entire division in tie-replacement work … They are often employed in connection with large rail renewals."

Vanderblue (1917, 115), Professor of Transportation at Northwestern University, studied the valuation of railroads. He identified problems associated with differentiating short run and long run costs, and the need for revenues to cover both. "Unless instrumentalities which are to be used for years are paid for by the revenues of a single day or year, the investment cannot be kept intact. The same principle is involved whether replacement is in kind is effected or additional units of plant are added. Both represent expenditures made for a future day."

A number of ICC cases involved testimony on the variability of costs. MOW costs were based on Federal wartime control allowance and not on actual studies (ICC 1920, 741-45).

Clark (1923, 274), of the University of Chicago, analyzed both short-run and long-run effects of additional traffic and concluded that one-half was variable in the short run. He was also cautious about what to consider as fixed costs for purposes in ratemaking, which should consider long-run variable costs. "… it would be fair to conclude that the least remunerative rate would be not much less than three quarters of the average rate for the country as a whole" (Ibid, 282).

Ely (1924, 67-70), of the University of Michigan, discussed capacity and returns to scale. In regard to a question on fixed costs, Ely replied "But doesn't this imply that the railroad possess a surplus of unused capacity? … This error in analyzing the character of transportation apparently springs from several sources: 1) The idea of capacity is not clearly defined as efficient capacity. A railroad can always, if required, perform service beyond its normal capacity, but this results in poorer service, added wear and tear on facilities, and an increase in the direct cost of transportation. 2) The early history of the railroad presents instances of the condition which Professor Taussig assumes to be normal and continuous. So far as main line mileage is concerned, the capacity for traffic expansion is far less today than in 1870. The condition of excess capacity is therefore no longer normal. 3) The meaning of the principle of increasing returns was not clearly analyzed. The great increase in traffic during the past fifty years having been accompanied by a considerable reduction in costs and rates, this decline is regarded as largely, if not wholly, due to the 'fixed-cost' principle, whereas it is mainly due to the operating of the principle of increasing returns, which applies to direct as well as joint cost." Ely pointed out that Taussig's testimony in rate cases was flawed: Taussig cited railroad officials in describing fixed costs, but also used the qualification that excess capacity was required for this condition.

Ely challenged the concept of fixed costs preferring the concept of increasing returns to scale. "The fact remains that, whatever the relation of cause and effect, rates have declined year by year (1890-1920) in close agreement with the increase in traffic density" (Ibid, 83).

Miller (1924), Professor of Railway Transportation at the University of Iowa, showed that from 1902 to 1923, property investment rose from 90 to 195 and revenue ton miles rose from 81 to 235 (1906 = 100). He found that one-third of maintenance of way expense was variable with traffic.

Jones (1927, 74-77), Professor of Economics at Stanford University, stated that less than one-half of railway expenses and one-third of MOW costs were variable up to the point of full utilization of the plant. He further defined fixed charges (interest on bonds, etc.) as constant provided that increases in traffic did not necessitate new capital outlays.

The **American Railway Engineering Association** (1929, 1406-8) found that one-third of MOW expense was variable with traffic.

The Oregon-Washington Railroad & Navigation Co. Lines in Oregon found that 50.2 percent of MOW expenses were direct (short-run variable) (ICC 1928, exhibit 16).

The Southern Pacific Co. summarized the out-of-pocket portion on MOW expenses (both yard and road) as 33.3 percent (ICC 1932, exhibit A-3).

Daniels (1932, 52-73) of Yale University believed that most railway infrastructure investment was sunk. "But its right-of-way with the attendant grading, both cuts and fills, with the sterilizing cover of ballast, its tunnels, culverts and ditches, if they cannot be utilized for rail transportation, are made hopelessly unavailable for any other purpose." He cited "a battery of economists" that estimated that one-half to two-thirds of maintenance of way expenses were independent of traffic. He identified the central problem with most of these estimates: "Unfortunately for the finality of the forgoing explanation that additional costs, approximately one-half of the average costs, always fix the lower limit for permissible rates on any particular variety of traffic, the assumptions on which it is based crumble perceptibly when we look at the railroad business, not a short range but in the long run. … The qualifications, it will be recalled, are that there will be no essential change in the physical make-up of the property, and that it will always have surplus capacity so that it can handle the additional traffic without impeding traffic already moving. The fact is that both of these assumptions are belied by experience. Not only are additions and betterments being made continuously, but chief among the reasons for their making is the increasing volume of traffic. … Not only will the fixed charges increase, but the current costs of Maintenance of Way and Structures will be augmented. It is well enough to say that ties rot rather than wear, but if track mileage has increased under the pressure of heavier traffic there will be more ties exposed to weather that will rot and that must be replaced than there were before. The same thing is true of other items of maintenance. Every additional ton of traffic that has been annexed, even though its revenue covered the immediate additional expense its carriage entailed, has hastened the day when increased capital investment becomes necessary and, with increased investment, increased expense of current maintenance. … Naïve jubilation over the railroad's supposed tendency always to bask in the sunshine of increasing returns if often rudely shattered when the sobering necessity not infrequently arises of finding money for permanent enlargements and improvements. From a long-time point of view it can be cogently argued that railroad transportation is more truly denominated an industry of constant returns." Daniels specifically targeted Acworth, Haney, Knoop, Jackman, and Ripley for these criticisms and cited the work of Lorenz to support his conclusions.

Chen (1935) prepared a thesis *Depreciation as Applied to Railroads* in which he discussed the competing theories and ICC cases related to the treatment of railway depreciation. He found that ICC rulings had been inconsistent and recommended the use of depreciation accounting on a "scientific basis."

Locklin (1935, 130-31), Professor of Economics at the University of Illinois, discussed variable and fixed costs and warned that apparent variability might not be real. "It never-the-less remains true that Maintenance-of-way expenses is largely independent of the volume of traffic if a given standard of maintenance is assumed. Railroads can, and frequently do, defer maintenance when business is dull and speed it up when business is good. This practice gives a semblance of variability to maintenance expenses; but the variability is more apparent than real, since differed maintenance is an expense properly chargeable to the period in which it is accrued." Locklin considered that part of the return on capital paid out as interest on bonds as a constant expense, but that part of return paid out in dividends as a variable expense. His opinion as to the variability of return on capital was ambiguous. "But in discussions of economic theory a return on capital, or so much of it as is a normal return, may be properly considered as a cost of production. This is so because capital must in the long run receive its reward, or additional capital will not be forthcoming when needed. Interest on investment is therefore considered to be a constant expense. It is sometimes said that in the long run the return on capital is a variable expense. The more traffic there is, the larger the plant becomes, and hence the greater the investment and the greater the sum necessary to pay a return on the capital invested. This is true, but for the purpose of explaining certain characteristics of railway rates, it is necessary to assume a given physical plant. When this is done, interest on investment is clearly a cost which is independent of the traffic handled."

In 1936 the ICC made the case that investment was variable with traffic growth (ICC 1936, 67). Lorenz, Director of Statistics at the ICC, stated in Docket No. 17,000 Rate Structure Investigation, "Although it may appear that a given railroad could temporarily greatly increase its traffic without correspondingly increasing its investment, as a matter of fact a large traffic growth will make itself felt in the investment account." The 1936 report laid the foundation for the establishment of uniform rail costing methodology that eventually emerged in 1939 and 1940.

Healy (1940, 197), Professor of Economics at Yale, expressed the view that costs varied with the level of traffic except for very light density lines. "… the additional cost in the long run may be almost the same as the average over-all cost … most main-line railroad facilities and the operation thereon have had a chance to become closely adjusted to the level of traffic handled and the revenue derived therefrom, so that the average costs tend to be nearly uniform over a wide range of densities and the costs of handling additional increments of business are not likely to be much below the average costs." He found flaws in earlier studies.

Daggett (1941, 314-19) of the University of California recognized that variability of costs depended on the time horizon and discussed the variable nature of capital investment. " … it is not completely true that the capital in a railroad enterprise is irrevocably committed to that business. Terminal lands can be put to other use, machine shops may engage in non-railroad work, equipment may be allowed to deteriorate, and money normally used for maintenance of way may be invested elsewhere. Operations of this sort may to a certain extent, reduce the amount of capital in a railroad business. … It is to be remembered in this connection that a small withdrawal of capital may produce a considerable effect upon service. It is not necessary therefore that the entire capital be withdrawable in order that constant costs exercise an influence on price. What is more important still, railroads normally require new capital each year so that they may expand their facilities to take care for the needs of expanding business. … Unless the aggregate returns from railroad service promise to cover interest on new investment such additional capital cannot continue to be raised. … For this reason a community must be prepared to pay the constant as well as the variable costs of railroad operation."

Edwards became the Principal Economist in Charge of the Cost Section at the ICC and the chief author of *Railroad Freight Service Costs in the Various Rate Territories 1939* (ICC 1941a, 3-5). This study was the forerunner of more extensive study later published in 1943. The study provided a detailed analysis of costs using procedures outlined in Rail Form A including variability estimates for 20 Maintenance of Way expense sub-accounts. For example, Water Stations expense was found to be 10% variable, ties (running tracks) 80% variable, ballast 80% variable, bridges 10% variable, etc. Most of the calculations were based on findings of the American Railway Engineering Association. The study estimated costs on the basis of several assumptions: (1) "out-of-pocket" expenses (not including any return on investment), (2) fully distributed costs including a return on total investment, and (3) and out-of-pocket and fully allocated costs including deficits being experienced by passenger and less-than-carload services cross subsidy. "Criticism may be leveled at the continued use of the word 'cost' under the wider interpretation here given to this term. The term 'levels of revenue needs' would probably be more proper when referring to levels IV ands V. For simplicity of reference, however, the term 'cost level' is applied uniformly to all figures."

The **ICC** (1941b, 54-55) Bureau of Accounts gave renewed consideration to requiring depreciation accounting. The Bureau decided that all classes of railroad property were to be subject to depreciation accounting except for ties, rails, OTM, ballast, and track laying and surfacing (ICC 1942, 52-53). The explanation for this exception was that replacements were more uniformly spread from year to year and cited the "shortage of help available to perform the detail work that such accounting would impose." The report stated that the change to depreciation accounting had been deferred for a number of years because of low railroad earnings and the fact that such a change in accounting would entail a large initial expense. The sharp increase in earnings in 1942 made this change possible.

Cost data introduced in ICC Docket No. 28300, *Class Rate Investigation, 1939*, were used for the initial development of Rail Form A formulae (ICC 1962, 85). The **ICC** (1939, 13) Section on Cost Finding was then created within the **Bureau of Statistics** in 1940 to further develop Rail Form A and additional studies were conducted in 1940 and 1941. The Section on Cost Finding eventually published an extensive review of cost procedures (ICC 1943). This provided a detailed description of costing procedures, estimated the variability of costs with regard to a number of factors, reviewed various studies on the cost variability, estimated the effect of added traffic on investment, and provided detailed responses to questions and criticisms of the study. The report concluded that total investment was approximately 60% variable based on a general study that found a 33% increase in traffic was accompanied by a 20% increase in investment from 1916 to 1930. The total investment was corrected for 1910-1914 price levels and the traffic periods and investment periods were slightly different (ICC 1962, 69).

Of particular interest was the response to Senate question #79: "Criticism is directed at the treatment of 100 percent of the value of equipment and 50 percent of the value of the road as variable with traffic with the traffic volume over a long-term period. It is pointed out that between 1929 and 1932 the traffic decreased by almost half, while the carriers' book investment in road and equipment actually increased by 3 percent. *Answer*. The percentage used is based on the long-term trend. It is not expected that a drop in traffic by almost half between 1929 and 1932 would be followed by a comparable reduction in the carriers' book investment. In view of the delay that occurs between the period in which the traffic volume changes and the physical additions to the plant can be financed and constructed, there cannot be an immediate response in the size of the plant to changes in traffic volume. After some lag, following the reduction in plant traffic starting in 1930, the railroad plant was contracting at an annual amount almost as great as that at which it had increased during the period of 1915 to 1930. See Chapter XII. In the criticism of the Bureau's study, 1921 was used as a base year in making comparisons. By referring to chapter XII, chart 16, it will be noted that the net ton miles for the year 1921 suffered the most severe decline in railroad history, more precipitate even than the annual drop between 1929 and 1932. The index of net ton miles per mile of road dropped from 146.09 in 1920 to 109.70 in 1921 and rebounded to 147.09 in 1923. Had the year 1923 been used as a base, the figures would show that an increase in the revenue tons carries 1 mile from 412.7 to 447.3 billion, or 8.4 percent, was accompanied by an increase in the investment from 21,439,000,000 to 25,062,000,000, or 16.9 percent. The investment, unadjusted for price level, was increasing at a rate double that at which the volume of traffic was increasing. On this basis the investment would be roughly 200 percent variable. Such a study, however, is subject to error in that the figures are not corrected for changes in the price levels with the result that figures reflect changing prices indexes as well as changing traffic volumes. Furthermore, the use of net ton miles alone does not correctly measure the increase in traffic handled in terminals over a period when the average length of haul was increasing. No consideration was given to the change in the cost of capital as reflected by interest and dividends paid. It is believed that the several approaches made by the Cost Section to this subject are relatively free from the errors that are inherent in the above approach. Attention is called at this point to one approach that the Cost Section made to this subject which shows the effect of traffic on investment based on the relationship of the investment per mile of road with the density per mile of road. This study showed the variable portion of the value to constitute 73 percent in the East, 65 percent in the South, 57 percent in the West and 65 percent for the United States as a whole. This analysis was based on the freight gross ton miles and the freight portion of the value. Had the analysis been based on the overall density measured by freight and passenger gross ton miles and the total valuation, freight and passenger, these figures would have been increased to 84, 80, 59, and 73 percent, respectively, for the territories above-named."

Metzman (1944), president of the New York Central System, speaking to the Economic Club of Detroit stated, "If our government-owned transport plant – our super highways, our waterways and our airports – were made really self-supporting, these developments could be made free from appropriations and from politics. … If this were done, private investment in railways could live along side of government investment. … Unless some solution like this is acceptable to the American people, I do not know how long the railways can get along without public aid and still provide the service the nation needs."

Lyne (1945) of the New York University submitted an extensive thesis on the reasons for constrained infrastructure investment, and the relationship between investment and output. "It is obvious that such part of the increased output of transportation which the railroads have achieved during the recent war, which is ascribable to improved and additional plant, must be credited primarily to the 1920's rather than to the 1930's, because there were no net additions to the plant in the 1930's" (Ibid, 32). Lyne provided evidence that suggested that while railroad capital was readily available for equipment that is mobile and can be recovered by creditors, it was not as available for infrastructure because of the riskier nature of the investment. Infrastructure investment risks were described as rate control actions by the government on one side and cost pressures on the other. " … it would not appear that the investing community is quite prepared as yet to provide large sums for improvements to the railway plant …" (Ibid, 41).

Lyne pointed out that during the 1920's and 1930's rail freight rates were also significantly constrained by intermodal competition, especially in the 1930's. "… there have been many individual adjustment of rates, mostly reductions made voluntarily by railroad carriers to meet actual or threatened competition from other agencies of transport, which resulted in a appreciable lowering of the general freight level. (Quoting 248 ICC 606)" Although the railroads were profitable during the war, it was clear that this resulted from a large diversion of traffic from other modes to rail, a situation that was reversed following the conclusion of the war**.** ICC Price Administrator Eastman stated, "… there has been a large diversion of traffic to the railroads from other forms of transportation, because of war exigencies … but clearly it will not be possible for the railroads to retain the large traffic … railroads will be faced with greatly intensified and modernized competition by water, highway and air. … it is not strange that the railroads should regard their present high earnings … as a reserve ... for the difficult times which lie ahead" (255 ICC 397). It was apparent that the extensive infrastructure investments made during the 1920's, which created excess fixed costs and bankruptcies during the 1930's, generated the transportation capacity needed during the Second World War. (255 ICC 404). The ICC warned that, unless railroads were allowed to earn generous returns in good times (in balance against the lean times), investment and rail services would be constrained. (255 ICC 408).

Lyne described the folly of shippers in taking a short run view of railroad services. "The shipper or receiver of freight, in a time of an over-supply of transportation services, is tempted to look upon 'the problem' as primarily one of maintaining competition, so that he may, by playing one supplier against the other, secure the maximum of service at a minimum of outlay. It is only after an experience of transportation shortage that the purchaser of transportation is likely fully to realize that assurance of a dependable supply of this service at a reasonable price is, really, his primary concern" (Ibid, 117).

In targeting the underlying problem of railway infrastructure investment, Lyne stated, "In any event, it is certainly desirable in the interest of maximization of national income that funds to be invested in new plant for transport (of all modes) be divided among several agencies on the basis of maximum utility per unit of outlay. Such division can scarcely be achieved when the provision of capital funds is left to the whims of politics, as is now the case with so large a proportion of capital investment in transport" (Ibid, 144). He identified the problem of competing with a subsidized mode. "… the cause of the peculiar troubles of the railways' from a standpoint of capital outlay is narrowed down to their comparative situation … with respect to … fixed plant which is supplied by the government. ... it is the prospective future capital outlays on government-owned transport plant rather than those made heretofore which are the deterrent to the railways credit-for-expansion position, because in the years' immediately preceding the war, it appeared that the railways' competitive position had become rather stable, at least temporarily" (Ibid, 50). The railways knew that their competitors were about to be heavily subsidized by the government, and were advised to limit their investments in "risky" infrastructure.

Lyne summarized key steps to reestablishing railroad capital investment. "1) limit capital outlays on future long-haul highways of the "super" category to those which can be financed by tolls levied on the users. 2) Retain present fees for highway use at approximately present levels on the average. 3) Set some dependable limitation beyond which the size of vehicles using the public highways will not be permitted to go. 4) Limit capital outlays on future improvements to navigation on inland waterways to those which will be supported by tolls levied upon users" (Ibid, 156).

Leonard (1946, 16-21, 281-85), Transportation Officer of the War Production Board, published a treatise on railroad consolidations, competition and the Transportation Act of 1920. "The thing that set the railroad apart from other business enterprises at a rather early date was the unusual burden placed upon it by unbridled competition. Two important factors distinguished the railroad business: first, the high cost and degree of specialization of railway equipment; and secondly, the large percentage of fixed costs that had to be met. So great were construction costs that considerable economic waste resulted if two roads were built where one could handle the traffic. … Intense competition, especially characteristic of American railway history, has repeatedly confronted the carriers with economic disaster, and repeatedly the carriers have reacted by consolidating. … The ICC reported a total of 445 consolidations in the nine-year period from 1880 through 1888. … The last decade of the 19th century witnessed an unparalleled wave of consolidations. … By June 1894, one-fourth of the country's rail mileage was in the hands of receivers. … On the positive side, the lure of profits resulting from promotion of these new and larger corporations and from the establishment of traffic monopolies gave added impetus to consolidation. Greater availability of capital increased the possibilities for financial penetration and manipulation, and several new means of securing control became prominent. … In 1902 nineteen systems controlled 168,321 miles of line, or 81 percent of the total …" Leonard stated that six groups of investors controlled nearly 95 percent of railroad lines in 1906. By 1917 railway financial structures had become shaky as the result of disproportionate increases in long-term debt and closed channels of credit. The consolidation provisions of the 1920 Transportation Act were intended to construct a rational national system of 21 carriers, but this was opposed by rail interests and was defeated in the 1920's (although not officially declared dead until 1940). The consolidation program of the Transportation Act of 1920 was deficient because it did not place enough emphasis on potential operating economies and relied on the questionable assumption that problems of weak roads would disappear when combined with strong roads. As Leonard noted, "consolidation of weak roads may not cure but may actually spread the disease" (Ibid, 281-85).

In 1947, the **Association of American Railroads** published *Railroad Finance*, a pamphlet that reviewed changes in railroad financial issues from 1932 to 1945. Railroad debt had dropped to 72% of its 1932 level as the result of basic changes in the industry. "From the beginning of American railroad history up to 1930, the rail traffic of the country consistently doubled in volume every 15 years, on the average. That meant that the capacity of the rail plant had been increased in the same geometric ratio, which in turn made necessary new financing — new money — if the railroads were to keep up with the needs of the country. This basic fact, so often overlooked, is the reason why railroads are so largely financed by sale of bonds. … The railroad industry has thus entered an era which it must rely, to a large degree, on a margin to be retained from current earnings, in order to finance its capital needs. … The importance of adequate earnings is thus doubly emphasized, because of its bearing on a) further reductions in debt, and b) ability to finance by the issue of stock. … The burden of debt has not been the primary cause of railroad difficulties … the primary source has been the failure to accord the railroads, even in good times, earnings not greatly above a bare subsistence level." The AAR cited a recent Supreme Court decision. "From the investor or company point of view it is important that there be enough revenue not only for operating expenses, but also for the capital costs of the business. These include service on the debt and dividends on the stock. By that standard the return to the equity owner should be commensurate with returns on investments in other enterprises having corresponding risks. That return, moreover, should be sufficient to assure confidence in the financial integrity of the enterprise, so as to maintain its credit and to attract capital." (320 US 603) [1]

The ICC Section on Cost Finding was transferred to the Bureau of Accounts and Cost Finding on March 7, 1948 (ICC 1962, 247).

The **ICC** (1948, 87) stated, "The percent variable for the capital outlay in the rail plant indicates a close correlation in the East and South to traffic density. The percent variable in these territories for the various mileage group ranges, with one exception, from 87 to 98. In the Western district the relationship is much less direct, … being 49." The overall percent variable for all roads was 89%. The regressions were based on a cross section analysis and not a time series analysis. The correlations were drawn between investment per mile of road (based on reproduction cost, land and rights, and working capital) and GTM density per mile of road. Although the correlations indicated an average variability of investment at 89%, the 50% variability estimate was retained from the original RFA study. The 1948 report reflected on the original reasons for the investment variability estimates. "A figure of 50 percent was used for the road property investment and 100 percent for the investment in the rolling equipment. The treatment of the investment in equipment as 100 percent variable was based on the assumption that the carrier's ownership of motive power and freight train cars would be adjusted (over an extended period and with some lag) to the needs of traffic. The use of a figure of 50 percent for road property and 100 percent for equipment is approximately equivalent to the use of an over-all figure for road and equipment of 60 percent. The latter is in accord with the conclusion reached above that the percent variable for plant investment was 50 percent or more" (Ibid, 89). Evidential support for the choice of 50 percent variable was vague. "Studies of prewar periods indicate that over the long run period the investment per mile of road in the rail plant expanded at a rate which was between 50 and 70 percent of the rate of increase in the traffic density" (referring to Ford Edward's report *Rail Freight Service Costs in the Various Rate Territories of the U.S.*). In summary, (1) the investment variability estimate was designed for medium-run application and not short-

[1] Federal Power Commission vs. Hope Natural Gas Company, 320 US 603 (1944)

run application, (2) little support was provided for the 50% estimate for infrastructure variability, and (3) the overall investment variability estimate that was chosen (e.g., 60%) was not consistent with the evidence that was provided (e.g., 89%).

The study also reported average variability of maintenance of way expense (with respect to GTM) for various sections of the U.S.: 127% for the U.S. as a whole, 149% for the Eastern District, 148% for the Southern District, and 98% for the Western District. The report stated "The concept that the rail plant or the maintenance of such plant can be held substantially constant in the face of upward trends in the traffic appears to have been no more true 60 years ago than it is today" (Ibid, 63).

In 1951, the **U.S. Department of Agriculture** conducted an investigation into factors affecting rail rates (USDA 1951, 29-30). "In its decisions in Increased Freight Rates, 1948, the Commission (ICC) discussed at some length the question of railway economy and efficiency. … the Commission criticized railroad efficiency, quoting from its 62nd annual report (1948) to Congress '… we are of the view that much more must be done to increase efficiency and reduce the costs of railroad operations. Opportunities of this kind extend from practices to … substantial capital investments."

In *Price Theory*, Joe **Bain** (1952, 83-84) of the University of California stated, "The costs of production of any particular aggregate or unit of output, thus, may refer to the monetary sacrifice of the firm in securing productive services used in producing that output. This, in turn, will represent that proportion of all money payments or other sacrifices in securing such services - past, present, or future - which the firm considers to be allocable to the production of that output. In a general way this corresponds to the amount of money the firm actually pays of contracts to pay to purchase the productive services needed to produce a given output. But not exactly. This is primarily because the firm may use some productive services which it does not purchase or 'pay for' directly but in the using of which in production it implicitly makes a monetary sacrifice. … this sacrifice is equal to the payments which these services could secure in their most remunerative alternative employment - in general their market value as determined by other uses. It is thus necessary in arriving at the full cost of production to add to payments made or contracted for purchased services, an imputed value of non-purchased services used in production, an amount sometimes called the 'opportunity price' of these services. The cost of production of any output may then be defined as either the purchase price or the imputed value of all productive services used in producing the output and is equivalent to the total monetary sacrifice of the firm made to secure it" (Bain 1952, 83-84).

Edwards, now Director Bureau of Coal Economics of the National Coal Association, testified in support of rate discrimination and the appropriate use of out-of-pocket costs and fully distributed costs (1953, 9-10). "While the application of fully distributed costs as a basis for rates would no doubt eliminate rate discrimination, there is little doubt but that it would also eliminate the railroads as we know them today." On the subject of investment and operating expenses: "It has been the more or less continuous stream of capital outlay which alone has served to continuously hold a substantial segment of the rail operating expenses constant in the face of the prodigiously rising traffic volume and traffic density. The 'ultimate capacity' of the rail plant is no doubt as far off today as it ever was."

The **ICC** (1954, 64-81) updated the earlier study *Rail Cost Finding Procedures and Principles* and found that from 1939 to 1952 that rail plant investment was 25% variable with traffic density (in terms of GTM per mile of road). The study repeated previous vague statements on infrastructure investment variability. "Studies of previous periods indicate that over the long-run period that investment per mile of road in the rail plant expanded at a rate which was from 50 to 70 percent of the rate of increase in the traffic density." The 1954 study reproduced tables and charts from the 1948 study indicating that overall investment was 89 percent variable with changes in traffic and made no attempt to develop new estimates based on more recent data or more current techniques.

Meyer (1953, 50-56) of Harvard University estimated fixed and variable costs for the periods 1947-1950 and 1952-1955 and discussed differences between long-run and short-run marginal costs. He identified the problems in determining variable costs by conventional accounting and statistical approaches. "Railway depreciation practices appear to be based on assumptions of continued railway monopoly in the field of transportation and the virtual absence of technological change in railroading. It is apparent that developments in the past ten or fifteen years have made such assumptions unrealistic" (Ibid, 58). Meyer believed that infrastructure investment costs can be classified into variable and 'threshold' subcategories. He stated, "surprisingly, however, investment in equipment … are not closely related to output…" in contrast with the assumptions made by Ford Edwards and the ICC in the development of Rail Form A methodology (i.e., 50% variable road investment and 100% variable equipment investment) (Ibid, 55). Meyer also found that the variable portion of capital costs for freight traffic had risen by 10% between the two periods ('47-'50 vs. '52-'55).

Earley (1955) of the University of Wisconsin discussed changes in cost accounting practice with respect to marginal costing requirements for pricing and other management decisions. He cited a series of articles published by the American Association on Cost Concepts and Standards in *Accounting Review*. He hinted at earlier problems with cost accounting methodology. "Cost accounting principles appear to be fast incorporating the wisdom of the economists. … Although the analysis uses many short cuts, these follow fairly faithfully the logic of marginalism and profit maximization; at least some of them, moreover, are backed by operations designed to test and validate them."

In **1957**, the ICC Bureau of Accounts and Cost Finding re-visited the question of whether track property should be subject to depreciation accounting rules (ICC 1962, 80). The bureau found that the practice of charging replacement cost of track property to operating expense should continue since it was an accepted procedure and found satisfactory for more than 50 years.

Smith (1959) identified the change in the marginal cost function when output was expanding in contrast to when output was contracting. "With a divisible capital good, output expansion can occur promptly along the long-run marginal cost function. However, for output contractions, the immediate adjustment will be along the short-run marginal cost function. … Fundamentally, replacement is concerned with minimizing the cost of producing a given output. … In its pure form, replacement, as such, is a problem in least cost production, and should be so formulated. … Replacement and repair are simply two alternative ways of maintaining the productive presence of capital goods."

Locklin (1960, 153-54) discussed the relationship between density and cost variability and attributed the relationship to a change in proportion of total variable costs to fixed costs. He cited the work of Ford Edwards for his conclusions.

Borts (1960) found decreasing per unit costs with increasing density in Western railroads and in Southern roads. In contrast he found increasing costs with increasing density in Eastern roads.

Healy (1961) provided several performance measures that were negatively correlated with scale above 10,000 employees and below 5,000 employees, indicating that there was an optimal size for railroad systems at the time. He found that density was positively related to return on investment for western systems, but not for southern or eastern systems. He concluded that the maintenance share of revenue is "so greatly affected by factors other than density and scale that no significant relationship with scale is demonstrated."

Poole (1962, 20-27) demonstrated that railroad maintenance expense had both variable and fixed portions in relation to output and density, and that such ratios depended on the individual characteristics of each railroad. He avoided making any definitive statement about the degree to which expense was variable stating only that in some situations it has been found to be 90% variable and in others, 5% variable. Poole observed the relationship between investment (capital accounts) and expense (maintenance accounts), stating, "there was evidence of 'leakage' (though unavoidable) from capital accounts to the maintenance accounts."

Baumol (1962, 89), Professor of Economics at Princeton, discussed incremental railroad costs. "The increase in total costs resulting from an expansion in a firm's volume of business is commonly referred to as incremental cost. This cost is of vital economic significance. For the businessman it provides an essential guide to his production and pricing policy. … In determining incremental costs, it is necessary to distinguish between sunk and prospective investments. Sometimes the pertinent incremental costs involve making added investment (e.g., cars and locomotives). In that event all the added costs to be incurred (including use-depreciation and cost of capital) should be recognized as incremental. … Forward looking costs are essential because the pricing decisions they must guide necessarily look to the future." On the subject of differential pricing, "Differential pricing is consistent with the public interest in the economical utilization of resources. … If volume promises to build up substantially over time, the likelihood and cost of the required expansion in capacity must be recognized in the computation of the price floor" (Ibid, 92-94).

The ICC (1963, 64-65) Bureau of Accounts and Cost Findings revisited the original 1948 study *Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs* and repeated the findings in its 1954 study. On the basis of data from 1939 to 1952 it found that rail plant investment was 25% variable with traffic density (GTM per mile of road). The study repeated earlier statements for its variable investment formulae. "Studies of previous periods indicate that over the long-run period that investment per mile of road in the rail plant expanded at a rate which was from 50 to 70 percent of the rate of increase in the traffic density."

The Association of American Railroads (1964) published *A Guide To Railroad Cost Analysis*. The report included a study of cost variability and provided statistical tests for the analysis (i.e., significance tests, coefficients of determination, etc.). The AAR identified a relationship between railroad size and Maintenance of Way cost per GTM that rose asymptotically as the size of the railroad decreased. The report explained: "A logical explanation can be found in the availability of improved technology and in the utilization of this technology. On smaller roads, it is probably that a larger proportion of the track work is done manually, while the larger carriers' use of highly mechanized equipment has, to an important degree, replaced manual labor with automated processes."

The AAR report criticized Rail Form A as taking an "unduly long-run view of railroad costs." It concluded that, with under-utilized rail facilities, rail price floors should not take a view of costs that "blindly assumes a continuous replacement of fixed facilities … Such an approach to cost analysis is essentially static and ignores the dynamics of changing operations, volume changes, technological and design innovations, and the shifting cost functions relating thereto." The report criticized the inclusion of a return on one-half of road investment in variable cost estimates. "A similar defect of Rail Form A as usually applied is the prescription of a 4-percent (after tax) return on investment in equipment and a like return on one-half of other investment as an 'out-of-pocket' or variable cost of capital. No such arbitrary dictum can apply uniformly to the many different circumstances encountered in the railroad industry. … Furthermore, and most important, because the application of Rail Form A tends generally to overstate the extent of cost variation caused by changes in traffic volume, cost floors for rail rates that are derived with its help are often artificially inflated." It is important to note that AAR's objection to the use of return on investment applies to the determination of rate floors and not rate ceilings in periods of under-utilization. On the subject of depreciation, the report stated "Obsolescence and deterioration of facilities … are not traffic related to any significant degree."

A report prepared for the Under Secretary of Transportation, U.S. Department of Commerce discussed the relationship between fixed and variable costs, pointing out that long run variable costs could include changes in physical plant required for changes in traffic (**Systems Analysis and Research Corporation** 1966, 47-48). "If existing plant is already fully utilized before new loads are placed on it, these new loads may be accompanied by unit costs much higher than those which would be incurred if the transport enterprise had time to expand its load-handling capacity in the most efficient possible way. … In addition, the opportunity cost of assets about to be acquired, i.e., the price that must be paid for them to bid them away from other users, may be a great deal higher than the opportunity cost of retaining assets already on hand." The report goes on to describe the formation of the ICC Cost Section in 1939 in response to the need for development of costs for rate making purposes. "Cost finding for rate making purposes is a progressive science which involves accounting principles, economic theory, engineering studies, statistical procedures and most of all a practical knowledge of the transportation industry. To be the most value to all concerned, cost finding procedures must keep abreast with changing conditions and must therefore, remain flexible enough to readily reflect current changes." It stated that the first edition of Rail Form A was developed in 1941, with additional revisions in 1948, 1957, and 1963 (Ibid, Appendix IV-B, Note 72).

Friedlaender (1969, 32-34) of Boston College critiqued the ICC assumption that all railroads were producing under identical increasing returns to scale. "However, railroads differ dramatically in terms of their relation of output to capacity. At any given point in time, it is highly unlikely that any given railroad will have costs that are 80 percent variable. Since the ICC insists on applying the same percentage variable to all railroads, its estimates of out-of-pocket costs are often meaningless for specific point to point movements."   She described the use of the return on 50% of road property as being based on the conclusion (in regression estimates) that the percent variable for plant investment was 50 percent or more (ICC 1963, 86-87).

Kahn (1970, 73) stated, "even to the extent that depreciation does vary with use, what belongs in the marginal cost calculation is not the book cost, the writing off of investment cost historically incurred, but the amount by which this and other capital costs will be higher than they would otherwise be in the future by virtue of the incremental production in question. It is for the higher future costs or the decline in future values — not for fixed, historically sunk costs, — that the marginal production is causally responsible; it is only the future, not the past, costs that will be saved if the production is not undertaken. Notice how, at once, the traditional practices of public utility price regulation diverge from economic principles. … Suppose, as is probably true of much railway plant, production of the additional service is the only possible use of the equipment in question, present or future, and that outlay cannot now or in the foreseeable future be sold for a price that covers the additional depreciation, or the cost of the eventual additional repairs, attributable to operating instead of not operating. As long as users will pay a price covering the immediate price. … In this case, the buyers will have been subsidized by the stockholders who made the mistake of financing the capacity in the first place."

"Depreciation, too, goes into cost of service and price; but it is not a money outlay in the year it is charged. It is an imputed cost, introduced to take account of the fact that the economic life of capital assets is limited; to distribute the decline in their value – which is a genuine cost of production – over their economic life, in order to assure its recoupment from customers. So the portion of total revenues it permits the company to earn does not, as in the case with normal expenses, go out in payments to outside parties – suppliers of raw materials, workers, and so on. It belongs to the owners; it is part of the gross return they are permitted to earn on their net investment. The return to capital, in other words, has two parts: the return of the money capital invested over the estimated economic life of the investment and the return (interest and net profit) on the portion of investment that remains outstanding. … Any economic discussion of depreciation should really consider it along with the return on investment" (Ibid, 32).

Kahn clarified the relationship of demand, excess capacity, and marginal cost. Using a roadway bridge in an example, Kahn stated, "Notice how the intensity and elasticity of demand help determine the level of marginal costs. For those hours of the day at which demand is insufficiently strong or responsive to a toll covering only operating expenses, long-run marginal costs include only those operating expenses; for those times of day at which demand is strong or not responsive to a lower toll as to cause congestion, LMRC necessarily includes capital costs as well" (Ibid, 89).

"What gross cost of capital (depreciation plus return) should be entered into the economically efficient price? … Setting aside the consideration that capital costs as such do not enter at all into the computation of short run marginal costs, clearly it is an average of future costs of capital over the planning period that properly belongs in LRMC" (Ibid, 111). He supported the use of reproduction cost as the correct cost of capital, and that it should include a return on capital: "it is definitely the current and future – not the historic – capital costs that are relevant" (Ibid, 115).

Kahn described how regulatory pricing constraints could lead to sub-optimal results. "The way for a company to decide whether to replace a piece of machinery (or plant or other equipment) is to compare the average variable cost of producing with it (AVCo) with the average total cost of production with the new equipment (ATCn). Only the variable costs of the old can be saved by turning to the new; the choice therefore is between continuing to incur those AVC, on the one hand, or incurring the ATC – including the capital costs as well – involved in purchasing a new machine. If the AVCo are smaller than the ATCn it is economical to continue to use the old capital goods. But if, regardless of the fixed costs of the old, the AVCo are the greater, it is foolish not to scrap; every moment of continued production with the old means a greater drain on the company's resources, a greater avoidable cost of production, than would be involved in replacement. … But it need not be true for a regulated company. That company cannot ignore the fixed costs on existing assets, because the regulatory commission may or may not choose to include them in its cost of service once the assets have been replaced ... And the moral would seem to be that when this occurs, a regulated company will be deterred from replacing assets with economically more efficient new ones unless it is permitted to continue to charge the customers the capital costs of the unamortized portion of previous investments. These customers will complain … but they are still better off than if the company refused to install the new, lower cost equipment for service them" (Ibid, 199).

Kahn argued that when investment is required to meet current needs, it should charged to customers now and in the immediate future. "Clearly the charging of depreciation raises interesting and difficult questions of who should pay what share of capital costs over time. We have already posed the question of the proper rate when a plant is built far in advance … the idle capacity is really for the benefit of future, not present customers … concentrating capital charges in later years. Precisely the opposite course is suggested with respect to an investment required to meet current needs, but which may be expected to become rapidly outmoded … In this instance, the investment should be written off rapidly … the effect would be to put the heaviest capital charges on customers now and in the immediate future – and properly so since it is for their benefit that the capacity is being built now instead of later" (Ibid, 122).

The ICC (1970) formally adopted *Rules to Govern the Assembling and Presenting of Cost Evidence*. " … differences in position regarding the proposed formulae … are greatly exaggerated where railroads are involved because of the substantial excess capacity in the industry's facilities. More use of anticipated costs, including investment, may eventually relieve somewhat the dilemma of the Commission."

Joy (1971) of the British Railways Board described how British Rail constrained freight investment because prices would not support long-run marginal costs. "British Rail bases its freight prices on the prices of its competitors and not the relative qualities of the services offered. … The role of long-run marginal cost is, therefore, as an investment indicator and not as a pricing constraint. Thus B.R. will be relating its long-run marginal costs to its prices, instead of the other way round. … Thus many of the prices already fall far short of the Government's 'long-run marginal cost' constraint. In such circumstances B.R.'s prices must be based on the maximum the market is willing to pay, which in turn depends on the competition of road hauliers, the private car, airlines, and buses. This means there is no *necessary* relationship between each price and the long-run marginal cost of handling the traffic concerned. … B.R. is under no constraint as to the availability of its services. It can provide or not provide them at its discretion, and in many markets there are available good substitutes for rail services, both passenger and freight. It is the existence of these substitutes which limits the price which can be obtained for rail services, and B.R. is therefore without any long-run opportunity to exploit a monopoly situation. Its past financial record indicates that, overall, monopoly profits are unlikely to be earned. And even if B.R. were able to earn monopoly profits, (i.e., profits greater than necessary to retain resources in a particular business), legislative restriction of its opportunities for expansion means that, under its legislative remit to maximize service subject to a break even constraint, British Rail is likely to invest in any potential monopoly situation with the effect of expanding output (either in volume or quality) to a point where monopoly profits are eliminated. … If prices are not to be based on costs, costs must be used to tell whether, and for how long, B.R. can profitably accept traffic at prices determined in the market. … British Rail's investment strategy is to replace assets only to the capacity which is justified by traffics which are able to bear their long-run marginal costs. In the future, investment will be made only in assets which convey existing traffics at a long-run marginal cost which is covered by their respective revenues, or in assets for new traffics which meet the same criterion. The use of market based prices will provide a clear indication of the opportunities for profitable investment in replacement or capacity-increasing assets."

Joy pointed out, that when several private British Rail companies had existed, "none was prepared to give up capacity for fear of not being followed by its competitors." But when the British Railway industry became one company, capacity reduction became a way of improving long-run profitability. He summarized the revised B.R. dictum. "All costs are potentially variable; as revenue totals fall below the long-run cost of the present system, revenue must be maximized to find which costs can profitably be allowed to remain fixed. … This method of control of long-run profitability, by accepting the market and by varying capacity, requires a different approach to the measurement of railway costs from that in the past." Joy discussed methods needed to tackle the joint and common cost problem, and developed a method to assess costs from a constrained investment viewpoint.

Fair (1972, 51-62), Professor of Transportation American University, provided insight into ICC theory and practice regarding the role of capacity and investment in rate setting. "All carriers are subject to decreasing costs up to normal capacity. Because of their cost characteristics … and due to the prevailing condition of unused plant facilities … railroads strongly favor incremental or marginal costs as a true basis for minimum rate relationship where different modes are in competition. It has been recognized by some supporters that incremental cost may involve added investment. However, the critics of incremental cost point out that railroad capacity is generally excessive and that therefore no replacement cost will be involved in the determination of a relevant incremental cost. On the other hand the fully allocated cost argument contends that the application of principle of inherent advantage should not rest upon the accident of excess railroad capacity which makes for an unrealistic determination of the economic carrier in the long run." Referring to the 1964 AAR *Guide to Railroad Cost Analysis*, Fair noted that efficiencies may be gained in operations (and technological improvements stimulated) by increasing traffic volume. He stated that bottlenecks could occur and inefficiencies could develop to the point that costs could actually increase with increasing volume. He discussed railroad cost analysis. "It is not at all surprising that the approach to railroad costs, as set forth in this report, is at substantial variance with that of the regulatory body. The purpose after all, is fundamentally different. … the objective of railroad cost analysis … is to indicate floors below which particular rates should not fall." Fair pointed out that the ICC never officially adopted the cost formulae used by Rail Form A.

Griliches (1972) criticized the ICC's development of average variable cost based aggregate accounts of the approximately 100 railroads in the sample. He found very little economies of scale in the railroad industry.

Sidhu and Due (1974) of the University of Illinois, in their studies of Class II roads, found that average costs decrease as either weight or distance (or both) increase.

Keeler (1974) discussed the problem of estimating costs as a function of output without including a measure of capacity. He argued that marginal maintenance costs should rise with output and developed a short run cost function using a Cobb-Douglas production function. He differentiated between economies of density and economies of size.

Kneafsey (1975, 145-50) of MIT contended that railroads had little specific knowledge other than Rail Form A to evaluate actual variable costs. "Most railroads firms today apply a modified ICC Rail Form A variable costing system to evaluate costs associated with the movement of a commodity between two destination areas. It is a well known fact that rail carriers, except in a very few circumstances, do not know what the real cost of an individual movement is on their road. The costs presented by Rail Form A are the average costs incurred by general cost centers of a railroad. … The deficiency in railroad costing is generally attributable to two factors: first, the reluctance of rail carriers to initiate innovative costing systems in view of the fact that the commission has traditionally 'clung' to the ICC Rail Form A costing as a basis for rate setting in defense of proposed rates; and second, the relatively new state of large-scale management information system applications for railroad companies. … The application of these cost concepts by the railroad industry and the ICC has concentrated on the use of accounting data sources and therein lies the problem. The historical emphasis has been on attributing costs to specific operations on an 'after the fact' basis; thus, for example, interest charges and capital costs of all types are allocated to operations throughout the system in development of the Form-A costs typically used for costing out movements. It is important in developing contemporary pricing strategies for the railroads to distinguish between concepts of cost that are applied in an historical accounting context and concepts of costs that are applied to an estimation of future costs. While the concept in each instance may sound similar in application, they clearly differ in substance."

Ferguson and Gould (1975, 181), of the University of Chicago, discussed explicit and implicit costs. "The pure economic profit an entrepreneur earns by producing commodity X may be thought of as his accounting profit minus what could be earned in the best alternative use of his time and money. These two elements are called the implicit cost of production. … Implicit costs are this a fixed amount (in the short run) that must be added to explicit costs in a reckoning of pure economic profit."

Friedman (1976, 107-9) provided a general definition of costs and profits when he served as Professor of Economics at the University of Chicago. "It is convenient to define total costs of a firm as equal to — or better, identical with — the firm's total receipts. Total costs then include all payments — which may be positive or negative, actual or imputed — to all factors of production, including the entrepreneurial capacity of the owner of the firm. These total payments of factors of production can be divided, at least conceptually, into three parts: (1) Unavoidable contractual costs ('fixed cost'). There may be some minimum sum that the firm is committed to pay to factors of production no matter what it does and no matter how its actions turn out. … (2) Avoidable contractual costs ('variable costs'). Another part of the firm's costs depend on what it does but not how its actions turn out. … The distinction between fixed and variable costs will also depend on the range of choice considered open to the firm. For example, there may be some costs that can be avoided by going out of business but that cannot be avoided so long as the firm produces any output at all. Such costs will be variable costs if the range of choices includes the alternative of going out of business; otherwise they will be fixed costs. (3) Noncontractual costs ('profits'). Finally, there are payments whose amount depends on the actual receipts of the firm; these we shall call noncontractual costs. … these payments are generally designated as profits. This term is, however, somewhat misleading. The actual noncontractual costs can never be determined in advance. They can be known only after the event and may be affected by all sorts of random or accidental occurrences, mistakes on the part of the firm, and so on. It is therefore important to distinguish between actual noncontractual costs and expected noncontractual costs. The difference between actual and expected noncontractual costs constitutes profits or pure profits — an unanticipated residual arising from uncertainty. … The difficulty is … there are simply no simple institutional lines or accounting categories that correspond to these distinctions" (Ibid, 149).

Gwartney (1977, 97) of Florida State University distinguished between accounting and economic profits. "Accounting costs often exclude implicit cost. For example, they always omit the *opportunity cost* associated with the use of the equity capital of the owners. Thus, accounting costs will understate the opportunity cost of production, while accounting profits will overstate the level of economic profits. … Economic profits exist only when the business is earning an excess over and above the opportunity cost of utilizing the assets owned by the firm. Losses result when the earnings of the firm are insufficient to cover both explicit and implicit costs. …

Opportunity cost is the highest valued option sacrificed as the result of choosing an alternative" (Ibid, 18).

Ryan and Pearce (1977, 230) discussed economic rent in *Price Theory.* "Economic rent is the difference between the actual earnings of a unit of input and its supply price. Opportunity cost and transfer earnings are synonyms for supply price. The actual earning of a unit of input is the price it receives for the selling of its services for a given period of time. Its supply price is the minimum sum of money that is required to retain it in its existing use."

Harris (1977) studied economies of density and found problems with the use of gross ton miles as a measure of output and track miles as a measure of capacity. He used revenue ton miles as a measure of output. He found significant economies of density when return on investment costs were included, and that fixed operating costs accounted for a significant portion of economies of density.

Lieb (1978, 40, 265) of Northeastern University discussed the problem of capital related to poor rates of return. "Not once since 1944 has the aggregate rate of return for the railroad industry reached 5 percent. The average rate of return on investment for American industry in general during the same period ranged from 9 to 12 percent. Consequently, railroads have experienced difficulty in competing in the capital markets. … A prolonged lack of capital infusion leads to a deterioration of plant and equipment and a resultant decline in traffic. In recognition of this capital access problem, on several occasions the federal government has established short-term loan guarantee programs to assist railroads in securing funds. These programs met with mixed response in the industry; in retrospect they appear only to have postponed eventual financial crisis. For example, all the major recipients of loan guarantees granted under the provisions of the Transportation Act of 1958 subsequently declared bankruptcy."

Lieb described some important aspects of the 4R act: (1) rates equal or exceeding variable cost could not be found to be unreasonably low, (2) no rate could be considered too high unless the ICC demonstrated the carrier had market dominance over the traffic, and (3) the burden of proof was shifted to the complaining party. [2]

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[2] Railroad Revitalization and Regulatory Reform Act of 1976, Section 101(a) (1976)

The **Department of Transportation** (1978) provided a comprehensive review of the financial status of the industry, causal analysis of the problems, and alternatives for the future. The report, *A Prospectus for Change in the Freight Railroad Industry,* was commissioned as a result of 4R Act mandate. The report found that in 1977, (1) the Class I railroads earned only a 1.26 percent rate of return on average investment, (2) cash flow was insufficient to renew the existing plant and equipment, (3) efficiency and service were declining as a result of deferred maintenance, and (4) that public control was probable in the foreseeable future given the status quo. Causes of the problem included: (1) changes in markets from heavy industry to high technology, (2) federal regulation, (3) labor productivity limitations, (4) subsidy of competitors, and (5) sluggish adaptation of technology. The report made several broad recommendations that led to the Staggers Act: (1) consolidation and coordination efforts and mergers in order to foster needed changes in its economic and physical structure, (2) implementation of user charges sufficient to recover government costs for highway and water investments, (3) further steps to deregulate the industry and provide more effect rate flexibility, and (4) alternatives for federal financial assistance. In regard to structural regulation, "Even though the United States has a private railroad industry, regulatory strictures … make it clear that rail transportation is, in both law and practice, a public service" (Ibid, 80). In regard to subsidy on intermodal competitors, "This market-oriented approach will not work, however, if Federal actions distort prices and give competing modes unfair competitive advantages" (Ibid, 103). "Federal subsidies causing distortions in the marketplace have accelerated the decline of the railroad market share and railroad rate of return. For rail to remain competitive … Government investment and regulatory policy must provide for equitable competition" (Ibid, 111). "Many problems continue to impede of a financially healthy railroad industry. Most importantly, regulatory and policy imbalances in the treatment of different transportation modes must be reconsidered" (Ibid, 133). In regard to economic regulation, "Congress intended that the market dominance provision of the 4R Act be used in a manner that reflects the generally competitive nature of the transportation markets served by the railroads. As interpreted by the ICC, however, the market dominance provision is far narrower than Congress intended. In view of the court's affirmation of the ICC's interpretation, additional congressional action should be considered" (Ibid, 133). In regard to accounting procedures, "The House of Representatives provided guidance to the ICC in defining variable cost as follows: … it is the Committee's intention that the Commission apply modern cost accounting and financial analysis and that items such as administrative expenses, depreciation, interest payments, capital expenses, and other fixed costs or costs which do not vary immediately and directly as a result of this service at issue shall not be included. In other words, it is the Committee's intention that variable cost shall be the direct operating expense or cost of providing the service to which the rate, fare, or charge applies. … The relationship between ratemaking standards and costing and accounting methods, while a highly technical issue, is not trivial" (Ibid, 120). "This report consistently notes the fundamental imbalance in Federal policy on the question of whether transportation companies should pay for their own rights-of-way" (Ibid, 129).

In hearings before the U.S. Senate in 1979, the ICC summarized changes made in rail costing and accounting as a result of the 4R Act (U.S. Senate Committee 1979, 84). "First, arbitrary allocation of costs to functions can be reduced: and second, we can better determine how each type of cost varies with the volume of traffic services. During the revision, we also updated financial accounting regulations to make them conform to generally accepted accounting principles. In addition, a new Uniform Rail Cost System is being developed in response to the 4R Act and it will revise the previous rail costing system. Revisions to costing methodology will now recognize differences in rail carriers' use of capacity in determination of costs. The variable costs of a particular segment of track can also be more accurately determined. The new methodology will normalize, i.e., smooth out, the fluctuations of unit costs from year to year resulting from deferred maintenance."

Section 307 of the 4R Act specifically called for a new system to determine fixed and variable costs. "(i) operating and non-operating revenue accounts; (ii) direct cost accounts for determining fixed and variable costs … ; and (iii) indirect cost accounts … and the method for the assignment of such costs to various functions …" The new system was to be designed to "assure that the most accurate cost and revenue data can be obtained with respect to light density lines, mainline operations, factors relevant in establishing fair and reasonable rates, and other regulatory areas of responsibility." The statute required that the new uniform system of accounts (USOA) be: (1) in accordance with generally accepted accounting principles; and (2) "cost effective, non-duplicative, and compatible with the present and desired managerial and responsibility accounting requirements of the carriers." No specific requirements were given for the new costing system (Ibid, 12).

Starrett (1978) addressed the problem of optimizing investment cycles and developed pricing rules that were complete (an optimal decision rule for how much capacity to build and when to build it) and operational (rules that are simple and use observational data). He stated that because investment is lumpy, "between construction dates, effective capacity falls either because of depreciation or because of demand growth, … the problem is to decide how far to let it fall before building again." He developed a demand growth rule that equated total project cost on one side to excess revenue over a time period, discounted at the growth rate of effective demand, and weighted by the ratio of the discount rate to the rate of growth of effective demand. He developed a physical depreciation rule that related the rate of interest to the exponential depreciation rate and then combined the growth and depreciation rules: "As the date of the next construction is pushed further and further back, the surplus from it ought to increase monotonically." He discussed the optimal scale of operations that was determined by the trade-off between the efficiency of large size operations (assuming scale economies) and the disutility associated with longer waits between construction. "It appears that scale will be smaller the more essential is the product and the greater the degree of time preference."

Brown, Caves, and Christensen (1979) studied long-run railroad costs using a unrestricted translog cost function. They found significant multi product scale economies and significant errors in estimating marginal costs (and scale economies) when restricted models were used.

The **Committee of Railroad Shippers** sponsored a detailed chronology of the Staggers Act, a summary of key sections of the Act, and compares it to pre-Staggers (after 4R) (Patton et al. 1980). Of particular interest is the conclusion that the impetus for Staggers started with the 1978 DOT study *Prospectus for Change in the Freight Rail Industry* of the financial prospects of the rail industry. "The Prospectus concluded that between 1978 and 1985 the nation's private freight railroads (excluding Conrail) would be $13-$16 billion short of the funds needed to replace track and rolling stock and repay debt. The *Prospectus* posed two alternatives: nationalization or giving the railroads expanded regulatory freedom. … In 1979 the DOT published a report entitled 'Innovation Versus Nationalization; Proposals for Change in the Nation's Rail System', which was based on the October 1978 Prospectus."

Teece (1980) of Stanford University discussed efficiency in the multi product firm. He proposed that if economies of scope were based upon common and recurrent use of proprietary know how or the common and recurrent use of a specialized and indivisible physical asset, then the multi product enterprise (diversification) was an efficient way of organizing economic activity. The article explains how a railroad could efficiently expand into new ventures, and how efficiencies could result from the existing multi product output of railroads.

Burns (1980) discussed benefits of renewal maintenance strategies. He stated that the goal of renewal based maintenance was to provide a higher quality of track over its life in contrast to ordinary selective maintenance where the goal was to maintain track to a minimum standard.

Wilson (1980) of Indiana University discussed the importance of capacity in the development of rail cost functions. "The notion and measurement of capacity in transportation are extremely important, but they pose formidable conceptual and empirical problems. … Decreasing unit costs related to increased density implies excess capacity in one or all of a railroad's dimensions — terminal yards, right-of-way, shops. Indeed, the economic definition of full capacity utilization is the volume of traffic beyond which unit costs begin to rise more or less rapidly. … since a railroad operation … consists of many interrelated series of steps or processes … and since each of these processes has a different capacity, increases in traffic can be expected to create rising unit costs in some processes before others. … there are many different variables that determine the capacity of a rail line." Wilson went on to point out the many factors that affect capacity (Ibid, 86-89). "Kahn is therefore correct as long as we remember that economic costs are prospective, not historical, and that if a shipment is to be repeated, all future costs associated with the prospective traffic need to be added. These costs include not only variable labor, fuel, etc., but also the variable capital inputs associated with the traffic" (Ibid, 63).

Caves et al. (1980) developed a generalized translog multi product cost function (for railroads) that used Box-Cox metrics for output in place of the log of the outputs. The use of the generalized translog form overcame many of the problems associated with the quadratic, translog, and Leontif forms.

Burns (1981) discussed how mechanization has improved the productivity of renewal process efficiency.

Caves et al. (1981) estimated railroad productivity growth using a flexible production structure by imposing a few restrictions. The cost estimates included a short run variable cost function that held infrastructure investment fixed. "The measurement techniques that we utilize permit the production structure to have any degree of returns to scales. In addition, we relax the assumption that the firm minimizes total cost, and assume instead that the firm minimizes the cost of employing variable factors subject to predetermined levels of quasi-fixed factors. … Our estimates of the variable cost model show that returns to scale are sizeable for U.S. railroads if output changes are accompanied by changes in haul and trip lengths."

Friedlaender (1981, Chapter 4), now at MIT, conducted a study of infrastructure capital, rail costs and profitability in *Freight Transportation Regulation*. She demonstrated that optimizing investment could result in negative profits, that revenues were generally below long run marginal costs, and that it was possible to earn normal returns on capital. She also demonstrated that as maintenance of way capital increased, overall variable costs declined, and found individual elasticities of factor demand with respect to maintenance of way capital.

The **U.S. General Accounting Office** (1981) estimated the impact of changes in accounting practices on railroad reported income. Their results are shown in Table 7.1. The data indicated that a change in accounting practices to make railroad reported income on the same basis as other corporations would significantly improve reported earnings. The GAO recommended that the ICC adopt depreciation accounting for track structure.

Table 7.1: Impact on Railroad Earnings of a Change in Accounting Practices

(Percentage Increase in Reported Net Income Due to Change from Betterment to Depreciation Accounting)

Railroad	1976 (%)	1977 (%)	1978 (%)
BN	87.5	84.6	65.9
SP	37.4	43.5	75.4
ATSF	62.2	57.5	47.3
UP	30.1	31.2	30.4
SCL	19.8	28.6	13.4
MP	29.7	28.7	29.0
N&W	21.5	20.5	31.1
B&O	59.7	23.9	46.2
Southern	21.6	24.3	26.5
C&O	12.2	16.0	27.0
Average	33.4	33.9	35.4

"Coal shippers in general have supported the use of depreciation accounting. This stems from the ICC's reliance on cost based approaches to rail regulation. A switch from RRB to depreciation accounting increases the investment base as track that was capitalized at values that may be more than fifty years old is raised to the value of its last replacement and then depreciated. At current capital costs, this increases the railroads' allowable return on investment. … However, offsetting this increase will be a decline in annual expenditures as track replacements that were expensed are capitalized. This has the impact of making carriers appear more profitable. It reduces the apparent revenue need and lessens the pressure to increase rates on captive traffic such as coal. … Recognizing that the Staggers Act ratios were developed with RRB accounting as the base, the ICC is considering what adjustments would be necessary to make the threshold ratios in the Act applicable once the accounting system changes are made." In Docket No. 36988, Alternative Methods of Accounting for Railroad Track Structures, the ICC proposed changing from betterment to depreciation accounting. In this case, the ICC proposed a methodology for accomplishing the conversion to depreciation accounting, and asked for comments on a number of aspects of the proposal. Specifically, the ICC indicated that it was considering revaluing track investment because track investment was understated in the previous accounting system. The ICC was also concerned that depreciation write-offs would not provide an adequate shield against inflation. "Because inflation is such a significant factor today, depreciation charges based on existing track book value will be so low as to not allow maintenance of the railroads' track assets. The serious under depreciation that would occur if no adjustment in existing track investment accounts were made would affect the ratemaking process" (Ibid, 5). The ICC described the various uses for railroad data in ratemaking proceedings and proposed a revaluation of track structure based on the last programmed replacement of a particular track segment. Depreciation accounts would be constructed based upon the remaining life of the asset. Depreciation rates were to be established as a function of traffic density with each line segment grouped into account by traffic density.

The Economic Tax Recovery Act of 1981 (ERTA) provided the railroads with special tax benefits for writing off the "frozen" investment base created under betterment accounting. Under this approach, the railroads could select the depreciation method used for various track assets within guidelines set out by the Act. All expenditures made under betterment accounting which had been capitalized but had not been retired as of December 30, 1981 could be depreciated at between five and fifty years. A railroad choosing a five-year write-off could depreciate forty percent of the base in year one. By 1985, the carriers were to convert to depreciation accounting for track related investments. In the interim, special write-offs were allowed to adjust the investment base. These changes had the effect of providing the carriers with tremendous tax benefits (Ibid, 138-39).

Gove (1982), of the University of Illinois, challenged the use of the ICC Revenue to Variable Cost (R/VC) threshold as an appropriate indicator of market dominance. "This study emphasizes the inherent difficulties of a national regulatory criterion when applied to a specific area. Since the revenue-to-variable cost ratio can be quite high for this region, which is relatively competitive, the relevance of the measure for other regions might also be questioned. The revenue-to-variable cost criterion of market dominance presumes a stationary demand where changes in rail rates are a result of movement along the demand curve rather than shifts of the total demand curve. Because of this the criterion is more applicable to areas where other modes are not relevant, and where there are few rail lines: that is where there are no relevant substitutes to cause shifts of the demand curve."

Starkie (1982a) of the University of Adelaide, disputed the common assumption that "road capacity is subject to pronounced lumpiness or indivisibilities" because capacity could be added in small increments or bundles. He defined a production function for road services and demonstrated that efficient road user charges should not diverge significantly from long-run marginal costs. He demonstrated that long-run marginal costs should include use-related costs plus the capital costs of expanding output at the margin when capacity was limited. "If capacity is infinitely divisible, the efficient investment solution is always to expand the capacity of a road till the user charge, short-run marginal cost, and long-run marginal cost are equal."

Starkie (1982b) discussed implications for public policy in *Pricing and Cost Recovery in Long Distance Transport*. "If, as suspected, lumpiness and increasing returns-to-scale have been overplayed, where does that leave the cost recovery issue? First of all it suggests that aiming not to cover costs, on the grounds that to do so is incompatible with economic efficiency is justified less easily, at least in the non-urban transport sector. It indicates also that is a user-pays approach was based on (long run) marginal costs then we should expect to recover at least a sizeable proportion if not all of total costs. … Secondly, there is a case for treating costs differently. … the focus would be upon the use of additional resources to provide for additional consumption. … with a pay-as-you-go treatment of capital investment. … annual expenditures on 'track' and vehicles are treated as current costs to be recovered from revenues on an annual basis. This was considered by the UK Ministry of Transport (1968) to be consistent with a long run marginal cost approach because decreasing returns will tend to be reflected in higher annual capital charges. The method is now used in both the UK and New Zealand to assess the appropriate level of charge on freight vehicles" (Ibid, 66-67). "It provides one justification for emphasizing an investment perspective, in what, traditionally has been seen as a pricing issue. Economic theory has been inclined to assume that to clear markets and reduce losses prices adjust easily, and without costs, to secular and spatial variations in the level of demand. This is far from being the case. Frequently there are severe pricing constraints. Railways have not been able to manipulate their rates, because of government controls and because of strong competition from alternative modes. Road prices have been constrained … Consequently, as the South Australian road data shows, often it is the level of prices, and consequently revenues, that are 'sticky' and, in contrast, investment which is flexible. … In these circumstances, therefore, it is arguable whether it would not be better to turn the problem inside out; to view the cost recovery issue as an investment issue and not a pricing issue. The analyst checks whether the level of investment in a particular sector can be sustained given the amount of revenue to be expected from users faced with inflexible prices. At the end of the day one wonders if this is not indeed the heart of the matter. If there is a future in a cost recovery policy then it surely lies in gearing investment decisions in the first place to a realistic assessment of the cash flow" (Ibid, 68-70).

The ICC (1982) Bureau of Accounts published technical documentation of the new rail costing system (i.e., URCS) to replace Rail Form. "The Uniform Railroad Costing System is a complex set of procedures, which transforms reported railroad expense and activity data into estimates of the costs of providing specific services. It includes the assemblage of the initial data base of expense and activity information, the development of cause and effect relationships, the calculation of unit cost and the application of those unit costs to the movement of specific shipments" (Ibid, 1-1). "In those cases where no acceptable regression results are obtained, Phase II relies on default procedures, which are based on either the treatment of similar accounts or Rail Form A procedures" (Ibid, 1-2). "The present URCS application does not require the use of any RFA default variables except for those related to the cost of capital allowance of 50 percent for road property and 100 percent for equipment property. These percentages are also applied to depreciation, retirement, rents and leased expenses" (Ibid, 1-6).

"Rail Form A calculated unit costs are based on the reported expenses and operating statistics for a single year. Because many maintenance cycles exceed one year, this procedure could result in large fluctuations in certain unit costs from year to year. This problem is intensified by the railroad system of betterment accounting and the problem of deferred maintenance which has received a great deal of attention in recent years. Betterment accounting provides for direct expensing of the cost of in-kind replacement for rails, ties, and other elements of the right-of-way and structures. Under depreciation accounting procedures, mush of this cost would be capitalized, placed in the railroads' investment accounts, and depreciated over the life of the property. Working together, depreciation accounting and the annualization procedures contained in URCS would tend to minimized variations in unit costs caused by economic fluctuations, deferred maintenance, and 'catch-up' expenditures" (Ibid, 1-3 to 1-4).

The ICC revealed its underlying philosophy of the nature of the railroad industry. "The railroad industry, from a technological viewpoint, is mature. While there are progressive changes in railroad technology and productivity gains, they occur slowly over time. Consequently, cost relationships are expected to yield stable results as additional years of data are included in the analysis" (Ibid, 3-2). This turned out not to be true as found by the AAR in its *Preliminary Cost Study* (1991) that found that cost variability changed substantially as additional years of data were added.

Section 212 of the Staggers Act amended Section 10741 of the Interstate Commerce Act to specify that different rates for different services were not discriminatory (ICC 1983a, 25). The Commission's concern was that "if too large a share of constant costs is allocated to services facing strong intermodal competition, the traffic may be lost to other modes." Remaining rail shippers would suffer because fewer of them are left to share the constant costs; "the economy suffers since traffic is shifted to less efficient modes; the railroad's plant deteriorate and service declines as traffic is lost and profits suffer; and, finally, cross subsidization becomes necessary to keep the system functioning." The Commission concluded that it was necessary to "put an appropriately large share of the burden of those costs on those shippers for whom reliable, high quality rail service is of greatest importance" (Ibid, 32).

"The Commission found two areas of common grounds between coal shippers and carriers concerning principles of maximum ratemaking and used these as a basis for developing maximum reasonable rate guidelines. First, the Commission noted virtually all parties to this proceeding are in agreement that the determination of the cost of moving coal should be a principle-determining factor in maximum ratemaking. The second area of agreement was that a rail rate should at least cover the full, long run cost of transporting the coal at issue."

"Recognizing then that costs were to be the major determinants of maximum rates, the major bone of contention was how to compute the actual cost of service and in particular how to determine the proportion of constant costs properly allocable to the movement at issue" (ICC 1980, 31). "In some of the western coal cases, the Commission had allowed the carriers a fixed plant investment additive to recover track rehabilitation costs that were incurred to carry new coal traffic" (Ibid, 33). In the interim guidelines, the Commission softened its stance on the use of investment additives recognizing that: "Failure to consider new investment in facilities used to service captive shippers would be inconsistent with our responsibility to encourage useful and socially desirable investment by the railroads. Movement specific investments must be rewarded if additional investments are to be encouraged" (Ibid, 35). "As defined by the ICC for purposes of Rail Form A calculations, variable costs are costs which over a relatively long-run period, and at the average density of traffic, have been found variable with traffic changes" (ICC 1977, 3). Some costs would vary over the short run with the volume of traffic, for example fuel costs, while others vary only over the longer run. Long run variable costs could, for example, include track upgrading (Ibid, 36).

"The question of equipment and investment additives which have arisen in the western coal rate cases have tried to handle the maximum rate issues by accounting explicitly for such long run marginal investment costs. Shippers have generally not objected to these investment additives on principle, but with the proviso that shippers not be required also to pay for facilities of like kind which they do not use. The courts have affirmed this approach and remanded these cases back to the ICC to handle the double count problem. The NCA [National Coal Association] approach conceptually solves the double count problem but doe not address the mechanics of implementation. Rail Form A costing throws fifty percent of road investment into the constant cost category. NCA presumably would argue that a larger portion of these investment costs should be treated as variable."

Heller (1983) provided a review of the numerous economic, practical, and accounting issues leading up to and surrounding the Staggers Act.

<u>Burns</u> (1983) discussed the variation in renewal strategies among international railroads.

Braeutigam et al. (1984) established that there were basic differences between railroad firms and that estimation of a cost function should consider firm effects. They included variables for service quality (using speed of service) and effective track (using mileage and investment exceeding depreciation). They found significant economies of density.

Caves et al. (1985) found substantial increasing returns density and slightly increasing or constant returns to overall scale. They considered individual firm effects by distinguishing route miles from infrastructure capital with variables for each (similar to Friedlaender and Spady). They used railroad data from 1951 to 1975.

In *Coal Rate Guidelines*, Ex Parte No. 347 (Sub-No. 1), the ICC clearly established a long run marginal cost standard (U.S. Senate Committee 1986). ICC Chairman, Reese H Taylor testified: "In adopting the final coal rate guidelines, the commission made significant changes to the interim guidelines in response to certain concerns raised by shippers. These changes include … (2) adoption of a long-run marginal cost standard to estimate any avoidable revenue need shortfall" (Ibid, 12-13).

In 1985 the ICC reported on the purpose and status of URCS. "This title (Title III – Railroad Cost Determination) provides for the creation of a Railroad Accounting Principles Board (RAPB) to establish principles for determining economically accurate railroad costs directly and indirectly associated with particular movements of goods." The Board was to establish these principles within two years of enactment of the Staggers Act. Once established, the Commission was to promulgate rules to implement and enforce them. The RAPB was not funded at the time the Staggers Act was passed. In 1984, Congress passed legislation funding the RAPB for fiscal 1985. On November 13, 1984, the Commission issued a decision to hold *Ex Parte No. 431, Adoption of the Uniform Railroad Costing System for Determining Variable Costs for Purposes of Surcharge and Jurisdiction Threshold Calculations*, in abeyance until the RAPB had the opportunity to review URCS. The proceeding was opened in 1982 to adopt URCS for limited purposes (Ibid, 25).

Johnson and Kaplan (1987, 156) discussed the history of management accounting and identified problems created by cost accountants in *Relevance Lost: The Rise and Fall of Management Accounting.* "The LSE [London School of Economics] economists recognized that the arbitrary systems accountants used for allocating costs to products made product costs virtually useless for decision making. R.S. Edwards, a practicing accountant before he turned to economic analysis, was particularly concerned about the inability of cost systems to predict variable costs. To an economist, the most important aspect of cost behavior was the extent to which costs changed with output." They also stated that engineers used the concept of the time value of money for project evaluation long before the cost accountants started to (Ibid, 163-164).

The **U.S. Senate** (1987) conducted extensive hearings on Staggers in "Rail Industry/Staggers Oversight". These included testimony from many individuals concerning the subject of investment in the rail industry. [3]

William Dempsey (President AAR): "If congress imposes an even more hostile government environment, railroad managers would have few choices; some indeed would have none. Access to capital markets would essentially be denied and internally generated cash would be the exclusive source for maintaining the physical integrity of the system. Faced with a similar dilemma, railroad mangers in the 1960's and 1970's, handicapped by a federal policy in cutting costs, resorted to across-the-board rate increases. Because railroads had long lost their market strength against other modes, this course led to massive diversions of traffic which further aggravated the cash shortfall. For many companies this ultimately led to deferred maintenance, for some, bankruptcy, liquidation. Shippers received poorer service at higher cost. To avoid repeating that scenario in the 1990's, those railroads that could, would shrink to the truncated core systems, operating mileage well below anything presently contemplated. Many communities and shippers would be deprived of rail transportation. If even that avenue of relief were denied by law, the economic viability of the industry in the private sector would be ended" (Ibid, 10). Concerning the underpayment of truck for their infrastructure use: "Rail competitive trucks almost certainly pay less (than the average truck), since the 65 percent refers to the average 75,000 pound truck and rail competitive trucks travel at higher loaded weights and have much higher annual mileages. Using a

[3] testimony given on June 9 & 17, 1987

methodology based on the 1982 HCAS (Federal Highway Cost Allocation Study, updated for 1985), the AAR estimates that rail competitive heavy trucks pay only about 50 percent of their cost responsibility. … Waterway users receive an even larger percentage of subsidy than heavy trucks. The Army Corps of Engineers spends annually about $575 million on shallow draft navigation — more than ten times the barge industry user charge payment of about $50 million. … Even by 1995, when the barge industry user charge is fully phased in, the barge industry will be covering no more than 15 percent of federal spending on its behalf. Assuming that the total of these annual subsidies to motor and water carriers are fully reflected in reduced rates, the competitive effect on rail rates is to reduce rail revenues by more than $1 billion annually. Where a competitor's costs are lower due to efficiency the railroads cannot complain; however there is strong ground for complaint where these costs are not lowered by efficiency but rather by burden of the costs of competing carriers (and ultimately their shippers) to other highway users or the general public, as the case may be" (Ibid, 13).

"During the 1981-1986 period, Federal tax laws had a very significant and most positive impact on the improved cash flow of the railroads. … the Economic Recovery Tax Act of 1981 materially enhanced cash flows. Among other things, that legislation required a change in the railroads' method of accounting for track expenditures. While prescribing longer recovery periods for money for future track outlays, it did permit a one-time recovery of past track expenditures which had not been depreciated. We estimate that the one time recovery of the so called frozen base produced as estimated $2.5 billion in added cash through 1985. Similarly, the continuation of the investment tax credit produced almost as many savings during this period. And ACRS depreciation also was beneficial. The principal benefits of the frozen tax base ended in 1985. Investment tax credits and ACRS were terminated last year so all of these sources of improved cash flow are now lost. Under the 1986 Tax Reform Act, we have estimated that railroad's Federal income taxes for 1986-1991 will be $2.5 billion more than under the rules existing prior to its passage if earnings remain constant. If rail earnings decline the losses will be even more severe. Those huge projected cash drains stem from the elimination of the investment tax credit, less generous depreciation, and a tougher alternative minimum tax — which overwhelm the gains made from lower corporate rates. Moreover, those figures do not reflect the real possibility that production by some of the railroads' capital intensive shippers will decline due to the harsher, new tax rules nor do they consider the stronger competitive position of trucks and barges which, because of their less capital intensive nature, were less disadvantaged under the new tax rules" (Ibid, 17). "In effect the (1986) Tax Act is a triple whammy for the railroads — it reduces the demand for rail services by key rail shippers, it reduces the relative costs of the railroads' competitors, and it increases the taxes on what profits the railroads manage to retain."

"Railroads have been disinvesting in recent years by retiring and selling assets which have not provided, and do not give promise of providing, an adequate return on investment. Disinvestment is not a positive development because it is a clear sign of inadequate earnings, and if earnings do not improve, the trend could continue to the point where the critical mass of railroad service is threatened. … The railroads have not made inadequate capital improvements since Staggers. The point is they have only made improvements to those segments of the system where there is some hope of recovering the investment, and … those segments are shrinking in number. The plant the railroads' are retaining is not deteriorating due to inadequate capital investment. … This is due in large part to the fact that (1) … marginal lines have been sold … (2) capital requirements for equipment in the past six yeas have been less … and (3) the now lost tax advantages of the old tax laws — particularly the write-off of the frozen base — covered a large part of the railroads' reduced capital needs in the past six years" (Ibid, 20).

"Profitability of intermodal service is not available at the AAR because the needed investment, other cost, and reliable revenue data are not available. However, a word of caution is offered in interpreting revenue-cost ratios to be a surrogate for return on investment. Revenue-cost ratios are ratios of revenue to average, variable cost, including a return on investment at the embedded cost rate. Those ratios do not include coverage of fixed costs nor do they reflect the full true costs of capital. In this regard, for any specific component of traffic, these ratios may be substantially above incremental or marginal cost, and also provide significant returns on investment" (Ibid, 22). " … to the extent of new investment, the railroads are anticipating rates sufficient to cover the cost of capital being invested. To the extent that anticipation is not realized, I am equally certain that rail managers would scale back investment" (Ibid, 23).

Regarding the Consumers United for Rail Equity (CURE) bill requiring track access at costs not exceeding the cost of the facilities: "Two implications of this change are obvious. First, the Congress would be expressly rejecting the condemnation standard which makes the owner whole. Second it would be adopting a cost-based standard which takes no account of the revenue lost by the landlord carrier and which limits the costs borne by the tenant carrier to those associated with the facilities 'actually being used'. The latter ignores the fact that a railroad is a system and, although each shipper does not use every element of the system, each benefits from the existence of the entire system because it creates economies of scale. Under the formula of section 9 it is quite likely that trackage rights would be sought only for the purpose of service the most profitable traffic. This cherry-picking would very likely take from the landlord carrier revenues disproportionate to costs, otherwise neither tenant carrier nor shipper could gain from the transaction. The wide-spread practice of cherry picking would ultimately weaken, if not destroy, the entire rail system because its effect would be to severely restrain the differential pricing necessary to recover total rail costs" (Ibid, 26).

Regarding the large amount of cash generated in the mid-1980s: "But far and away the most important factor has been the 1981 Tax Act. We benefited in two ways. One, as a capital intensive industry, we benefited by the accelerated depreciation that was granted in the 1981 Act, the five year write-off period, as did most of our customers, our shippers, who are also capital intensive. Beyond that, there was an enormously important cash generator provision in that bill. … It had to do with the way in which we treat expenditures on track, which is a big component of our capital expenditures. Before 1981, when we would replace track, we would write-off that amount as an expense in the year which taken. We had been doing that before the Federal income tax on corporations. We had been doing it forever. Treasury did not like that. It thought that we, like everybody else, should be under ratable depreciation for track replacements. We finally agreed to that primarily because of shortened ratable depreciation periods in the 1981 Act. We could see that we could phase into that period without undo damage to the industry. However, and here is the crucially important factor, the original track expenditures made by the industry, when the track was laid down for the first time, were put in what we call a frozen account. They were never expensed. They were never depreciated. And accordingly, Treasury obviously had to let us depreciate them" (Ibid, 41). "And so, we were permitted to do that over a five year period. That generated about $2.5 billion in cash for the industry. … Now that is all over, of course. That five-year write-off is over. We now have last year's tax act, which will bear heavily upon the rail industry because of the extension of the ratable depreciation periods, and upon our customers." Regarding the purchase of other industries by rail companies: "… when U.S. Steel bought Marathon Oil for billions of dollars, no one suggested that meant U.S. Steel was in good shape. What it meant was that it was retrenching and getting out of the steel business. To some extent, that is true of some of these purchases. The railroad managers look at these figures and they see a cloudy future for the industry. They want to manage their money in the best way possible for stockholders and they will put their money there instead of the rail business" (Ibid, 42).

"There is no question that the Staggers Act has improved the economic strength of the our industry. … The track is in good shape. Enormous capital investments have been made out of the cash flow that has been generated by the 1981 Tax Act. But the industry is well positioned. Its service has improved dramatically." Senator Exon: 'Let me point out here, just so we keep things straight here, that the question was with regard to the Staggers Act and what it has done to the railroads. The fact that the tracks have been fixed up, that is part of the Tax Act. It had nothing to do with Staggers, right?" Mr. Dempsey: "Yes. … I look at the provisions of the CURE bill and what I see, and what a lot of other people see, is an effort to move rail rates down to as close to 180 percent of revenue to variable costs as possible. Now there is not a cap as such in the bill. But the burden of proof shifts to the railroads when rates go above 180 percent. If I were the Commission and I saw that the Staggers Act contained no presumption of illegality at all — over 180 percent — and saw that the preexisting scheme with respect to burden of proof was retained in Staggers (on the shipper) … even were the Commission 'brain dead' … they would get the message. Rates would go down. … But if they [rates] did [go down to 180 percent], the industry would have been, in 1985, $77 million in the red. That is a going out of business sale. … If it were only partially successful and the rates went down to 200 percent on average … it would have taken … two-thirds of out net profit." The number of rail customers with no rail alternative (according to Kearny Associates) was estimated: "that 10 percent, maybe 15 percent, of railroad traffic was captive in that sense. … If you eliminate all the traffic below 180 percent, we would lose even more money" (Ibid, 49-51).

"There is a big difference, Senator, between being profitable and being revenue adequate. Profitable means you are making a profit. You may make a substantial profit, without being revenue adequate, because the test of revenue adequacy is a long range test of making the cost of capital. Now you can go for some period of time without earning the cost of capital and then you will begin to try to find ways to get to that level and you will retrench. The industry has been disinvesting now for decades. You disinvest more and more and more. You try to get to a core system. You cut your costs. You are always trying to get to that goal" (Ibid, 54).

"The test of revenue adequacy was established in the Staggers Act as the target for long-run viability of the rail industry. It is subscribed by some 56 economists in a statement that I am sure is in the record as the appropriate standard. … There are a lot of industries that do not make the current cost of capital, and in the end it will get them, and it will get us in the end" (Ibid, 55).

Darius Gaskins (CEO Burlington Northern Railroad): "One of the comments I would make goes along with what Mr. McKinnon [of NS] said on revenue adequacy. The issue of revenue adequacy is really a question of how much of our railroad do we replace. … Everything that is done to lower our rates to particular shippers, whether they be coal shippers or grain shippers or whoever or to further restrict our activities just means that in the long run we will operate less railroads. We are not revenue adequate, and that means we cannot afford to replace the whole plant that we have in place today. Quite frankly, the issue before us is how much of that plant will we be able to maintain over the long run?" (Ibid, 306). "I do not believe these rates of return are nearly as high as Congress envisioned when you passed the Staggers Act nor do I believe they are sufficient to attract the capital necessary to maintain and improve Burlington Northern's railroad system in the future" (Ibid, 309).

Voytko (Paine Weber rail analyst): “The salient features of that larger picture are these… First, that railroading is not a financially rewarding business at present. It offers low returns, minimal pricing growth prospects, very competitive pricing, shrinking market share, and serious regulatory and financial uncertainty for managers and shareholders. … The second … is that rail managements are withdrawing assets from the industry at what I think is an accelerating pace. In the seventies that took place through bankruptcy. In the eighties this is taking place through the more controlled means of abandonments, line sales, and the investment of funds outside of the railroad business. … The third point is that nearly all the forces in my view spurring the rapid contraction of the rail industry which can be influenced by changes in public policy — and that is a key point — can be traced to a set of problems linked to rail labor and Federal law. … The fourth point is that, viewed in this context, proposals to return to more restrictive economic regulation or to burden the transfer of lines to newly created regional railroads with labor protection…” (Ibid, 64). Responding to the charge that the rails are earning monopoly profits from captive shippers: “My only comment as a rail securities analyst is where exactly are these monopoly profits? The ICC ROI [Return on Investment] figures show no evidence of any pervasive above average returns. … Instances of monopoly profits must be rare since they seem difficult to find in significant micro-markets and in any case are not large enough in the aggregate to significantly improve the rails overall financial picture” (Ibid, 70). “Why must the rail industry be continually at regulatory risk despite its modest financial performance and prospects? Some of those present today, even those who believe the rails are sufficiently sound financially to bear greater regulatory burdens, may have had cereal for breakfast this morning, made and sold to them by companies which quite likely have ROIs considerably higher than the railroads. … Imagine the attention the rail industry would get if it merely earned returns equal to those industries whose profitability we contribute to with little question every day?” (Ibid, 71).

“Across the industry, there appear to be strong indications that the companies want to put less money back into the railroad business. They are selling off track assets. They are proud of their programs to reduce capital spending, and when they come to Wall Street they tell analysts how much they have reduced capital spending and how they hope to keep it low. So I presume that they are going to try as much as possible to keep capital spending down and reinvestment in the rail business at a minimum" (Ibid, 95). Regarding the CURE legislation "If the CURE shippers see reregulation as a movement toward a highly specialized railroad system, more economically regulated, designed to serve their kinds of commodities, then what happens to the other shippers? Are they supposed to go elsewhere or go to trucks? I would suspect that there are a lot of shippers in this country that would be upset at that notion" (Ibid, 102).

McKinnon (CEO of Norfolk Southern Railroad): "I said at the same time that that discussion was made that piggyback makes a contribution to our bottom line profit. It does not meet the test of sustaining new investment in that business, but it is contributing to our bottom line profit. And I went on to say that if … we can only haul it at a rate below our long term variable cost, we will have to drop that business. … Coal is contributing enough to make us keep investing in that business. Coal is more profitable than piggyback. But if we give up the piggyback, you are going to have negative effect on coal rates, because that profit that it gives, that bottom line profit without reinvestment, helps us secure the funds to make the new capital investments in coal and in the other parts, gut parts of our railroad" (Ibid, 343).

Barbera et al. (1987) used the replacement cost of capital instead of book value when calculating return on investment costs, and depreciation accounting instead of betterment accounting. The study treated replacement costs as expenses and found increasing returns to density, and constant returns to scale. The study identified the importance of using the current replacement cost of capital in cost estimates, but lacked measures of service quality, traffic mix, unit train operations, or measures of high and low density track.

Lee and Baumel (1987) estimated a short-run average variable cost function using 1983-1984 data finding 'mild' economies of density and constant returns to scale. They used elasticity of short run variable costs with respect to traffic to imply economies of density and did not include fixed costs in their cost function. The study found considerably smaller returns to density than other studies.

Kovalev (1988) found that high train densities could reduce reliance on renewal maintenance.

Westbrook (1988), Professor of Economics at Georgetown University, was contracted by the ICC to independently evaluate and test the regression study that supported the estimation of cost variability in URCS. One of the concerns was how URCS could affect the jurisdictional threshold. The study stated: "There has been a great deal of concern by both shippers and carriers that the substitution of new variability percentages for those in Rail Form A could materially change the amount of traffic subject to ICC maximum rate regulation. The RAPB [Rail Accounting Principles Board] recommended that the Commission implement a mechanism to prevent this from happening. Although the RAPB did not suggest a specific approach, it did illustrate several procedures that appear to be readily available. We are seeking comment on whether the adoption of new cost variabilities should be predicated on the adjustment to the jurisdictional threshold to ensure that the scope of regulation is not appreciably altered. … Specifically the RAPB recommended that variability be measured using cost elasticity rather than average percent variable; that nonlinear regression be considered as a basis for computing elasticity and that additional; variables such as traffic density be included in the model as explanatory variables. Dr. Westbrook rejects the RAPB's recommendations and proposes the use of average percent variable, linear formulations and exclusion of density as an explanatory variable. … The Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act) required the Interstate Commerce Commission (ICC) to develop a new and more accurate accounting and costing system. … The system was to include operating and non-operating revenue accounts, direct cost accounts for determining fixed and variable costs, indirect cost accounts, and a method for the assignment of such costs to various functions. The costing system requirements of the 4R act were augmented and reinforced by the Stagers Rail Act of 1980. This new Act requires the use of General Purpose Costing System (defined in the RAPB final report) to calculate costs to be used in certain specific regulatory applications, including establishment of cost-based standards that define the scope of the ICC's regulatory jurisdiction. … Research and development of the new costing system was completed in 1981. … It was subsequently found that as additional years of data were added to the data base the estimated regression equations changed substantially. Several of the parties commenting on the preliminary RCS expressed concern over the instability of the regression results" (Ibid, 2-3).

The Westbrook report discussed whether to use elasticity of average variability as a proper measure for jurisdictional threshold. It concluded that because the purpose of URCS is to estimate variable costs, the variability ratio (and not elasticity) was the appropriate measure. "Practical considerations compel us to adopt linear specification for the regression equations; given this specification, the elasticity and variability ratio are identical" (Ibid, 6-10).

The RAPB Final Report raised a number of policy and methodological issues that were not directly related to the formation of the regression equations. These included the cost of capital, treatment of productivity, and the substitution of depreciation accounting for the replacement, retirement, betterment accounting currently used in general purpose costing systems. The report used data based on the replacement, retirement, betterment accounting method and stated that the methodology should apply equally well to data constructed under depreciation accounting (Ibid, 11).

The report discussed the issue of time horizon: "The cost variability concept is supposed to summarize the dichotomy between costs that vary with output and costs that do not vary with output over an intermediate run time horizon. The intermediate run is defined in the RAPB Final Report as 'a time period during which some but not all capacity limiting input factors may be changed.' Availability of a panel data set allows estimation of both the long-run (fixed) component and the intermediate-run (variable) component of expenses. The fixed component is captured by the cross-railroad variation in the capacity variable. The variable component is captured by the variation in the output variable, controlling for railroad capacity. Having used the multiple regression to control for railroad capacity, the variation in output must be accounted for by the variation in variable inputs" (Ibid, 13). "URCS … is designed to provide benchmark 'costs' for particular regulatory applications … a compromise between the impossibly complex revelation of full detail that would be most useful for movement costing and the broad representation of general cost functions that would be least useful for movement costing."

"URCS methodology makes two crucial assumptions that related measures of railroad capacity to fixed inputs and measures of annual railroad output to variable inputs: 1) Annual railroad expenditures on fixed inputs devoted to the j^{th} activity are proportional to the capacity of the railroad, and 2) Annual railroad expenditures on variable inputs devoted to the j^{th} activity are proportional to the annual output of the railroad. As it stands, the representation imposes restrictions upon the behavior of the activity equations. First, there is no provision for expenditure E to change when relative prices of the inputs change; there is no way to reflect factor substitution within an activity equation. Second, this equation requires that the marginal expenditure with respect to capacity and the marginal expenditure with respect to output are fixed constants for all capacity/output combinations" (Ibid, 19).

Westbrook adopted, in his analysis, the "fixed effects model." The model restricted slope coefficient to be constant across railroads and over time, but allowed distinct "firm effects" and "time effects" to be captured. The assumption was that railroads behave similarly with regard to changes in expenses due to changes in explanatory variables. This specification was attractive because the differential firm effects captured cross-railroad differences that did not change over time, such as network, terrain and geographical location effects. The differential time effects capture time-wise variation that were constant across railroads, such as changes in macroeconomic conditions, the regulatory environment, relative prices, and general productivity trends. The major advantage of the fixed effects model was that it helped control for omitted variable bias. The major advantage of the panel data set was that it could exploit firm specific and time specific effects to control for omitted variable bias in the estimation of the coefficient of interest. The model was deemed appropriate for inference based on the effects actually present in the observed sample.

Westbrook attempted to use a logarithmic version of the model and found the results unstable. "This points up one of the primary advantages of the linear model in computing the ratio Rj: its flexibility" (Ibid, 33). He concluded that density could not be used in a multiple regression model because it was the product of gross ton miles and miles of track which were already (implicitly) accounted for in any model including these two variables. He also concluded that productivity could not be used because there was no appropriate measure (Ibid, 34-35). Westbrook found that individual carrier variabilities were significant and logarithmic models were unstable (Ibid, 55).

Rhodes critiqued Westbrook's report. "However, improved regression equations cannot validate the overall URCS framework, nor the variability ratios that are key components of it. This is a kind of reverse GIGO [garbage in garbage out] problem. Cleaning up the garbage does not validate the uses made of it, washed or not. Until URCS is put on solid footing by supplying appropriate conceptual foundation and requisite statistical sampling, it cannot be rescued by improved regression analysis."

Newbery (1988a) analyzed road damage externalities (costs to other vehicles from damaged roads) in relation to road maintenance costs. He found that given certain assumptions, the average marginal social cost of road use is equal to the average road maintenance cost. He identified the distortion in the U.S. system of allocating road costs to vehicle damage. "The optimal moment to resurface will involve balancing the extra costs of advancing the date of resurfacing with the lowering of vehicle operating costs, and will depend sensitively on the nature and magnitude of the road damage externality."

Newbery (1988b) demonstrated that only a fraction of the maintenance costs would be recovered if vehicles were charged only for the road damage they cause. "It is a standard result in the efficient pricing of highways that, if vehicles can be charged for the congestion they cause, and if there are constant returns to scale in expanding highway capacity, then an optimally designed highway has capacity such that congestion charges exactly recover the capital cost of the highway." He found that the standard method for allocating capital costs was "mistaken. Instead, all capital and a large fraction of maintenance expenditures should be allocated as congestion costs on a PCU (passenger car unit) basis if there are constant returns to scale in road construction." He developed a theory of congestion charges and congestion costs.

Oum and Tretheway (1988) derived the Ramsey pricing rule in the presence of externality costs. The result was that the Ramsey pricing rule was computed on the basis of the sum of marginal private cost and only a fraction of marginal externality costs. "In other words, the quantity shares under the (first best) social marginal cost pricing rule would not be preserved under Ramsey pricing." Their work raised the question of how to consider external service costs when the Ramsey pricing rule is used to determine prices in regulatory situations, specifically if service costs be considered an external or internal cost. The question arises as to whether marginal cost pricing implies a homogeneous product requiring equivalent service quality. If so, then Stand Alone theory should also require an equivalent product.

Joy (1989) provided a comprehensive review of railway cost studies and highlighted the errors of the high fixed cost argument and marginal cost interpretation. "Railway policy was profoundly affected by the belief that a very high proportion of railway costs were fixed, and that, as changes in volume would only affect the small proportion of costs which varied with output, rates for new traffic need only cover those obviously variable costs… This argument depended on three conditions: 1) That the costs of a railway did include a high proportion of fixed costs; 2) That only new traffic was priced to cover only the 'low' variable costs; 3) The that revenues of all the other traffics covered all the other costs. … The most important condition is the first: the whole argument depended on the validity of the assertion that most railway costs would remain unchanged in the face of changes in traffic volumes" (Ibid, 47). "The fallacy of this approach to railway pricing by partial marginal costs is that eventually all traffic becomes marginal traffic. … The theory was right: welfare is maximized, and there is no misallocation of resources, as long as the outputs of an enterprise are priced closely as possible to the marginal costs of the resources consumed in their production. What was wrong was the railways' estimation of the amount of their resources which were consumed with production, and which would not need to be consumed if production were reduced. This error, which first saw the light of day in 1956, persisted through the following decade, despite some compelling evidence to the contrary — which incidentally was based on British Railways' own data … These misunderstandings about variability and controllability of railway costs have not been limited to Britain. In the United States, the convictions of many railroad managements, that a railway company, by its very nature, had a core of fixed costs which would not rise if the scale of the company's operations were enlarged, but could not fall if the scale were reduced, were a major basis of the merger movement in the 1960's. This flew in the face of a number of academic studies … Most recently, beginning with the work of Keeler (1974), and extending to the modern translog cost models of Caves (1981), has come the distinction between economies of density and economies of scale. Certainly, increase in traffic over a given infrastructure will be met by less than proportionate increase in costs. However, when the long-run adjustment of infrastructure to the level of traffic is fully allowed for, the cost elasticity is much higher than it was conventionally thought to be. When the scale of a railway as a whole — the length of its route network, number of terminals and so forth — is changed in proportion to traffic, then costs change roughly in the same proportion. It is thus when changes in the volume and scope of traffic handled are sufficient for discrete changes in the scale of the undertaking that the assumption of high fixed costs is most erroneous" (Ibid, 48-49). "In the face of these studies, railway managers could have such a fundamental misunderstanding of the process under their management only because they were confused about the effects of excess capacity, thinking that it represented something fundamental to, and unavoidable in, the railway process. Possibly this arose because, in the working lives of most railway managers, excess capacity had been a normal situation: … The belief of railway managers that extra traffic could always be accepted with only a small increase in total costs was based on short-run cost evidence which could mean either (as they believed) sharply decreasing long-run average costs or excess capacity. … The technical or managerial reason most commonly offered for the continuance (of excess capacity) … is that railway capacity is variable only in discrete lumps, and that variations may be made only at long intervals, when major assets are due for replacement. But short run effective plant capacity is determined by a combination of the physical assets and the chosen operating pattern. … This stochastic variation of actual railway output means that the conventional economists' approach to the use of marginal cost is of limited usefulness, because it assumes a constant product (quality) and a perfect knowledge of future demand."

Jorgenson (1989, 10) of MIT conducted a series of studies on capital formation and its economic impact and described various methods of capital measurement. "In the correspondence between the perpetual inventory method and its price counterpart, investment corresponds to the rental price of capital and replacement corresponds to depreciation. … Depreciation may also be expressed in terms of present and future changes in the price of acquisition of investment goods… The average depreciation rate on the acquisition price of a capital good, is a weighted average of replacement rates with weights given by the relative proportions of changes in future prices in the acquisition price of investment goods in the current period. … The definition (of depreciation) preferred by most economists, including ourselves, is the economic depreciation is the decline in the value of an asset through time. … Replacement … is the level of investment necessary to maintain the productive efficiency of the capital stock. … The appropriate definition of capital stock depends on use … For questions of productivity and factor inputs, the appropriate capital stock is cumulative investment less cumulative replacement. … Replacement is equal to depreciation only when productive efficiency declines geometrically as the asset ages" (Ibid, 456).

Winston et al. (1990) estimated the effects of railroad and trucking deregulation on shippers, carriers, and labor. They used a 'mode choice probability' model to estimate the amount of money shippers could sacrifice following rate and service quality changes and be equally well off. They found that, under deregulation, shippers had a large increase in welfare, railroad profits increased, and railroad wages fell. With single line and interline competition, they found significant increases in consumer welfare for all commodities except coal and grain.

The Association of American Railroads (1991) submitted recommended revisions to URCS. The AAR made a number of suggestions including new account groupings and new equations with improved statistical properties. AAR stated "it is possible that further examination could lead to more extensive and fundamental changes than AAR proposes here. AAR's research not only identified weaknesses with statistical costing, but has suggested there may be non-statistical costing procedures (such as engineering approaches) that ultimately will produce better estimates of cost variability than do statistical methods, at least for some account groupings." The AAR study ran into statistical problems when developing cost equations for maintenance of way expense "… there are indications that the AAR regressions for some account groupings may not be fully consistent with industry operational practices. For example, engineering research demonstrates that maintenance-of-way expenses are more closely tied to gross ton miles than to car miles. However, equations with gross ton miles did not meet the statistical requirements the AAR established for acceptable equations, whereas equations with car miles did. The unrealistically low variability for TRMAINT (34.45% when linear functional form is used) coupled with the relatively poor fit of the regression for this account grouping (RMSEF of 23.84) have led AAR to continue to examine non-statistical means of calculating variability for this account grouping" (Ibid, 26).

Dooley et al. (1991) estimated a short-run variable cost function while reexamining total factor productivity since deregulation using data from 1978 to 1989. Their study included measurements of high and low density track speed (as a measure of the quality of capital), percent unit train shipments, percent of traffic interlined with other carriers, high and low density gross ton miles, and firm-specific dummy variables for service quality and 'effective track' (mileage and investment in exiting track). Similar to Lee and Baumel (1987), they used elasticity of short run variable costs to imply economies of density and excluded fixed costs and found moderate returns to density.

Chapman et al. (1996) found that companies that face liquidity constraints change their investment behavior in "Cash Flow constraints and firms' investment behaviour." Those firms that did not face liquidity constraints were more likely to make capital investments are based upon the merit of the investment, whereas those that were constrained were more likely to have Free Cash Flow affect investment considerations.

Foran (1997) stated that railroad engineering departments were improving their planning coordination with transportation and marketing departments.

Kramer (1997) stated that railroads had improved material handling and production systems that were used in large renewal systems. He found that most of the recent maintenance of way productivity gains came from high production equipment.

Zarembski (1997) illustrated how improved component management had reduced railroad maintenance costs.

Joy (1997) reviewed the history of British Railways from 1963 through 1997 and discussed the freight pricing philosophy of BR and Railtrack. "Freight covers the marginal infrastructure costs it imposes on a railway which capacity is determined by passenger needs, and Railtrack, and BR before it, would have been worse off without freight's contribution. In recent years rates on the remaining traffic appear to have been set to maximize net revenues, rather than a cost-covering exercise to maximize volume and so limit freight on the roads, which would have been the socially optimal course for a public owed utility. For BR, the question was how much could be extracted from each traffic. From the statement of the new owners of the trainload business about prospects for growth, and the growth already achieved, it now seems evident that BR may have tried to extract too much."

Kavussanos (1997, 147-58), City University Business School, London, conducted a comparative analysis of industry risk for U.S. transport industries and found railroads had the highest risk among them. In regressions conducted over the periods 1984-1995, 1984-1989, and 1990-1995, using both multifactor modal estimates and APM estimates, railroads consistently higher betas than air transportation, trucks, water transportation, electricity, gas, petroleum refining, and real estate. "Based on the estimated numerical betas of the transportation sectors, their ranking in ascending order is: Water (0.941), Trucks (0.968), Air (0.976), and Rail (1.011). Their ranking is preserved in the second, more recent sub-period."

Brennan and Kramer (1997) illustrated how railroad maintenance planning had improved through improved information technology.

Feitler et al. (1997, 157-69) identified key factors that affected Less-Than-Truckload (LTL) truckers' ability to adapt and change strategic focus in response to external and/or internal motivators. External factors such as recessions and fuel prices reduced the pace of strategic change. Industry turbulence (in terms of entry and exit from the market place) and national level legislative changes increased strategic change. Older firms and those with positive past performance changed less, newer firms and those with negative past performance exhibited greater strategic change.

Button and Nijkamp (1998, 13-24) examined competition in Network Industries as a result of E.U. policy of increasing competition in networks such as railways. They identified economic features of networks, stability issues and policy options. "The economic evidence is that recent market liberalization has, in general, enhanced the technical and dynamic efficiency of network industries in the transport and telecommunications sectors. Markets, however, are not static entities, and there are inevitable shifts over time on both the demand and supply sides. In normal circumstances this may not pose any serious problem. Given the basic characteristics of network industries, however, there is the possibility that instability may result and, in the extreme condition, no supply being provided despite the net economic benefits that exist.

In other words, network industries may be characterized by an empty core if competition is fostered. … Policy may take a number of courses, but it is unlikely that there is any ideal approach to handling the problem of empty cores. … If the considerable investments which now go towards developing infrastructure networks are to achieve their primary goal of enhanced spatial economic integration, it is important that effective policies for tackling empty core problems be derived."

Jensen (1998) studied Swedish Railways to determine whether efficiencies brought about by competition were enough to overcome the costs that might result from loss of scale, vertical sub-optimization, and transactions. He found that, with a vertically segregated railway, competition (for transport services) would result in net efficiencies. He also found that competition would have resulted in net costs with a vertically integrated railway.

Looney (1998) found no relationship between rail track expansion and economic growth using World Bank statistics. "Per capita income, country size, and economic growth are often seen as being major determinants of rail track expansion in developing countries. However we could not empirically verify these explanations for rail expansion using recent World Bank data for a set of 35 developing countries. … Rail track expansion seemed to have little relationship to economic growth."

Oum et al. (1978) provided an extensive review of productivity and efficiency measurements in rail transport including Fishlow (1960), Kendrick (1961, 1973), Meyer & Morton (1975), Gallop & Jorgenson (1980), Kendrick & Grossman (1980), Caves, Christensen and Tretheway (1980), Caves, Christensen and Swanson (1981), Grabowski & Mehdian (1990), Gordon (1991), Duke et al. (1992), Wilson (1997), and the STB/ICC (1997). The authors described difficulties with capital input measures. "The most contentious input measure is capital. Capital is a stock from which a flow of services is derived. Ordinarily, capital is measured in currency units rather than physical quantities. In order to weight capital relative to other inputs (Cost Share Weights) it is necessary to have capital expressed in current dollars. The most common procedure is the Christensen-Jorgenson (1969) perpetual inventory method. Historical investments are accumulated for each year, converted to constant dollars by a price index for capital assets, less an accumulated rate of economic depreciation. This method assumes that all capital investments were 'used and useful'; that is, there is no provision for inappropriate investments, a dubious assumption for many railways. Obsolescence must be reflected in the assumed depreciation rates; that is, economic depreciation is used, not regulatory mandated or tax based depreciation rates. These are still stocks, rather than flows. Rental or leased capital, typically, is incorporated by deflating lease payments by a price index to put leased capital on an equal footing with owned capital. If we assume a constant service flow from capital stock, then the growth of capital stock provides a measure of the growth of capital inputs (flow) for calculating aggregate input quantity growth. This assumes that a given stock produces a flow of capital services for that year, independent of the level of actual output. This 'lumpy' flow of capital services assets measured TFP (total factor productivity) to fluctuate with the business cycle; hence the measured TFP may vary from ear to year. TFP growth is best thought of in terms of productivity trends rather than specific year to year values. … Although the Christensen-Jorgensen (1969) perpetual inventory method of measuring capital is preferred methodologically, it is very data- and time- intensive. Simpler proxies for capital measurement have been used; for example, miles of track as a proxy for the size of the aggregate investment in way and structures (see Roy and Cofsky, 1985). … The correspondence between these proxies and actual capital stocks is problematic; they may be reliable for equipment capital, but are less convincing for way and structures capital. It is still necessary to construct cost share weights, so it is necessary to convert whatever measure of capital into a current dollar equivalent expenditure for comparison with other input expenditures. To construct the cost share weights, the imputed expenditure on capital is calculated by multiplying by a service price of capital. This is the imputed required return to cover the costs of using a unit of capital. This is measured as the rate of economic depreciation plus the cost of capital, and may include a capital gains component if capital assets are appreciating in value because of inflation."

Baumol and **Willig** (1998) discussed the application of stand-alone cost rules to bottleneck routes. Of particular interest is the short discussion of the implications of stand alone costs ceilings for excess capacity. "… the current rules preclude the recovery of excess-capacity costs — that is, of any capacity for which there is no current demand, and for which no sufficient future demand is in prospect. The rules do so by imposing the stand-alone cost ceiling on the prices of O-D [Origin-Destination] services. Stand-alone costs are defined to be the costs of an efficient firm, and any firm that is burdened with excess capacity cannot be a most efficient supplier. Thus, current rules prevent any recovery of the costs of such excess capacity."

Waters and Tretheway **(**1998) raised the issue of capital in a comparison of total factor productivity and price performance. "The capital stocks are measured using the Christensen-Jorgenson perpetual inventory method; … The capital stocks include three categories: way and structure capital, equipment capital, and land. Capital stocks were accumulated since the earliest days of the railways, revalued each year by an appropriate asset price index, plus that year's investment and minus a measure of economic depreciation (no depreciation for land). The capital service price includes real depreciation (zero for land capital), the costs of capital (distinguished between debt and equity) minus appreciation of the value of capital assets; all this is multiplied by a tax multiplier than incorporates effective tax rates, including capital consumption allowing for tax purposes."

The **U.S. House of Representatives** conducted extensive hearings that were led by the Committee on Transportation and Infrastructure House of Representatives (1998). Testimony was provided by Anthony Hatch, Alfred Kahn (Economist), Stephan Month (Credit Suisse First Boston), William J Rennicke (VP Mercer Management), David A Wyss (Chief Economist, Standard and Poor's DRI), Karen Phillips (Senior Vice President of Policy - AAR) and Hass (Professor of Finance, Cornell, consultant to NERA) regarding the revenue adequacy issues facing the railroads.

William J Rennicke stated that railroads had increased productivity taking $25 billion out of their cost structure since 1987, of which $20 billion was passed on to shippers. He warned of slower productivity growth. "In recent years, however, the productivity improvements for key items have slowed down. … What we are seeing is a substantial shift in the source of productivity available to the railroads. They have exhausted the operating productivity that was left in the system in 1980 when Staggers came. They were able to find billions and billions of dollars in productivity without having to rally invest heavily in capital during this period. Going forward, the productivity will have to come, quite frankly, from a substantial increase in capital well beyond the rates that they currently have. … If you use any metric, and one particularly good one is EVA, or economic value added, the railroads have not had a positive EVA for at least the last 10 years. And when you look at the key components that drive EVA, volume, revenue yield, operating ratio, capital turnover and the cost of capital, you find no signals that EVA will turn positive in the future. … The merger and other productivity benefits have plateaued, and will be declining. Other types of productivity are flattening out, and really the only major source of productivity change will come from capital improvements. … So the cost cutting and productivity gains have allowed the railroads to narrow the gap between return on capital and the cost of capital in the case of steadily declining yields. However, it is unlikely that the industry can sustain this historic rate. Productivity improvement was achieved by the rationalization of assets and resources in the last 16 years. In order for railroads to remain competitive and grow, they will need to find new sources of productivity, and we believe this can only come from massive borrowings of external capital. … In order to attract capital, the railroads will have to demonstrate that they can equal or exceed their cost of capital, and therefore, injecting any type of uncertainty into the structure of the system at this point, we believe, will severely diminish the railroad's ability to borrow capital at attractive rates to fuel the further productivity improvements" (Ibid, 124-25).

Month described productivity improvements since Staggers but warned of future doubts. "Going forward, however, once again the sources of cost savings are not clear. Savings due to deregulation have been achieved, under performing assets are off the books, and not much, if any, significant consolidation opportunities are left. So while growth in earnings in the railroad industry post the Stagers Act have been just over 9 percent per year, the EPS [Earnings per Share] of the S&P 500 has grown at 10.4 percent. … Going forward, however, the railroad industry is likely going to find it difficult to grow earnings even at this pace, and since the capital markets value companies more on earnings growth potential than anything else, the prospects for access to capital are somewhat hazy. … Since 1990, the railroads have invested more in capital expenditures than any other major U.S. industry sector. Certainly no mode of transportation faces these kinds of capital costs… In general, the railroads require about three times as much capital as the average S&P industrial company. Looking forward, these capital expenditures are not likely to end anytime soon. The high rate of investment is not slowing. My colleagues at Mercer Management estimate that over the next decade the railroad industry will have to significantly increase its capital expenditure budget in order to sustain its economic viability. … We have established that the railroads have relied heavily and will continue to rely heavily on external sources of debt and external financing. The problem that the industry faces from Wall Street's perspective is that investors demand a particular rate of return on the investments they make. The lower the likelihood of earning such a return, the less likely it is that the investment is going to be made, and the less likely it is that the capital will be available to the railroads. … The attack financial analysts make on the railroad industry is that it never earns its return on capital, and indeed the railroads pay that gap, the difference between their cost of capital and return on investment, from new money that they raise from investors year after year. Now this money has been and will continue to be forthcoming, but only on the expectation that the railroads will eventually return at least, if not more than, their cost of capital. This expectation is not unfounded since the gap between return on investment and cost of capital has been narrowing, in fact, since 1980, yet the prospects for earning the cost of capital diminish as earnings growth prospects diminish… unless an environment conducive to growing revenues and earnings is created, the railroads are going to find it costlier to raise the money to maintain the infrastructure…" (Ibid, 125-27).

<u>Kahn</u> argued that railroads were not revenue inadequate because market-to-book ratios were approximately two to one. "That tells me … that the investors see every prospect of earning more than the cost of capital. Therefore, they are willing to bid up the price of securities to twice the amount of dollars that are actually invested in the companies. … Now if in those 18 years (since Staggers) the industry had continuously fallen short of earning a competitive ate of return, which is the market cost of capital, where did they get thee crazy investment — investors willing to pay hundreds of millions of dollars into the securities of these companies?" Kahn stated that cost of capital measurements by the ICC and STB should be discredited (Ibid, 127-28).

Hatch: "… capital needs are huge, but the Street is skeptical. Unlike what you have just heard (from Kahn), the rail stocks have under performed significantly. They have missed this great bull market, and they are trading at a 40 percent discount to the Street average, to the average S&P 500 stock. That reflects Wall Street's skepticism about the railroad's ability to grow. … Without the likelihood of improving returns, investment capital will dry up, and remember the market is based on expectations, not on what is happening now" (Ibid, 131).

Wyss was critical of Kahn's reliance on price to book ratios because "much of a railroad's valuable resources is carried on the books at near zero book cost" (Ibid, 132).

Month (on cross exam): "The concern is not that tomorrow the industry is going to be denied access to capital, but the concern is that the cost of that capital is going to increase because investors don't believe that the railroads will have enough opportunities to grow their revenues and grow their earnings. That is the equity markets. … With the debt markets, the analogy is similar. … To the extent that the capital expenditures of the railroads continue are exorbitant rates and at rates that well in excess of the ability of the railroad to generate cash, to generate earnings, to generate EBITDA [Earnings Before Taxes, Interest, Depreciation and Amortization], one of the measures we use a lot, the cost of that debt capital is going to increase, and you are going to end up with a vicious circle because the higher cost of the debt increases, the greater pressure is put on earnings. The greater pressure that is put on earnings, the more the stock price is going to be hurt and impacted" (Ibid, 132-33).

Hatch discussed railroad stock discounts. "They are trading at a 40-percent discount to the average stock in the market. In 1993, when things seemed – the future seemed bright and we were not in a congestion crisis – they were traded at a 10 percent discount" (Ibid, 133).

Bachus (Stephan Bachus, representative from Alabama) pointed out that market to book ratios for other transportation companies were far in excess of 2-to-1. "… for example United Airlines has a book value of -$8 but is selling for $90, Delta with a nook value of $12 is selling for $125." Kahn countered that these were speculative stocks and that railroads were able to sell massive securities. Hatch countered that this was only possible because the securities were sold cheaply. Month cited concerns about the 2-to-1 ratio, stating, "And I think just two times book value is actually sort of close to perhaps a liquidation or a bankruptcy-type of level. If you look at a company that is valued at one time book value, that is basically what can be realized in a liquidation scenario. … And the issue here is that if the environment going forward is not conducive to continued revenue and earnings growth, stock prices will go down, P/E [Price to Earnings] ratios will go down in the railroad industry, which make the cost more costly to issue stock, rates on debt will go up, and what will happen is those earnings will be squeezed and the railroads will ultimately find it very difficult to generate any positive earnings at all" (Ibid, 136).

Rennicke: "So they (the railroads) have exhausted the non-capital items, they are now facing the only way that they can find productivity, which is to buy more efficient technology in machines and things that they have avoided more or less over time, and that is where productivity is going to come from" (Ibid, 137).

Phillips testified on differential pricing. "Differential pricing by railroads benefits all shippers. If the railroad shipper who had other options stopped using rail service, the contribution he was paying (however small) toward the fixed plant would be lost. Consequently, coverage of those fixed cost burdens would fall to the smaller group of remaining more rail dependent shippers. … The economics become even more obvious when visualizing the actual rail traffic base. The revenue to variable cost ratio at which all traffic must move, on average, if all railroad costs (variable and fixed) are to be recovered is 138 percent [based on 1996 URCS]. But the average R/VC ratio of all traffic under 180 percent is only 108 percent. While this helps pay the carriers' fixed cost burden, a significantly greater proportion of the fixed cost must come from traffic carried at rates in excess of 180 percent. … If differential pricing were curtailed, marketplace efficiencies would be sacrificed. Low-demand rail shippers would gravitate to other modes. As this cycle progressed, railroads would be increasingly unable to recover their large fixed costs, and disinvestment in the rail system would inevitable follow" (Ibid, 305).

Hass criticized the STB's Revenue Adequacy Determination. He critiqued ROI calculations because they included one-time "special charges" and that the denominator (investment) included acquisitions or mergers at market values not book value or depreciated original cost. He stated that cost of capital calculations mixed before and after tax costs of debt and equity, and that they should be based on the book value of debt and equity. He stated that they also used a cost of equity that was based on constant dividend growth, and that the cost of preferred stock was undervalued. He provided a detailed analysis stating that there is no meaningful relationship between STB's measure of revenue adequacy and the financial well-being of railroads. In support of this he stated that: 1) market values exceed book value, 2) railroads were retaining earnings instead of paying those earnings out as dividends, 3) adequacy should not be based solely on revenue but on operating ratio, 4) railroads issue debt that is rated as investment grade, and 5) cost methodology was in error. On this last point he stated, "Under the Depreciated Original Cost (DOC) methodology, the rate base is the depreciated original cost of the net assets (assets at cost less accumulated depreciation) less accumulated deferred income taxes and the return on the equity-financed portion of the rate base is set in nominal terms (such as 13.4 percent as used by the STB). As accumulated depreciation increases over time and the rate base declines, the cost-based price of the service declines, other cost-of-service components held constant. Under the Trended Original Cost (TOC) methodology, only the real portion of the return on equity is reflected in current rates; the inflation component of the return on equity is deferred until a later date. Hence the TOC rate base is greater than the DOC rate base by the accumulated deferred return balance. The TOC methodology produces pricing that start at a lower level than those under the DOC methodology, and these cost based prices drift upward over time rather than downward, as they would under the DOC methodology. However, if a regulated entity were pricing its services using a TOC based scheme, in the early years of the life of the rate base (or, more generally, during the time when the firm is adding to its asset base), its revenues will appear 'inadequate' when measured against those necessary under a DOC methodology. … The STB's methodology is effectively a DOC based approach to cost of service. Yet, it is logical that railroads should be using a TOC based approach to pricing their services over time (so that prices tend to rise with inflation). Hence, it is entirely possible that the test applied by the Board is yielding false-negative results: railroad revenues appear to be inadequate, but are factually adequate when judged according to the inter-temporal scheme under which they are being played out" (Ibid, 395-404).

Braeutigam (1999, 57-97) provided a comprehensive review of modern developments in transportation cost theory. He began with a critique of the basic fixed/variable cost equations and notes early misgivings by Taussig and Clark as to the 'arbitrary' allocation of common and fixed costs. He then described production functions developed by Klein and Hasenkamp, cost functions developed by Nerlove (cost functions depend on costs, output, and factor prices), Spady and Friedlaender (hedonic cost functions used to simplify output measurements). Braeutigam discussed the limitations of the Cobb-Douglas cost functions and its direct relationship to the translog cost function. "Cobb-Douglas … is a special case of the translog cost function…" A concise illustration and description of economies of size, density, scope, cost complementarities was included along with a summary of important econometric (transportation) cost studies conducted in recent years. He identified the necessity of accurately describing variable costs in short run cost functions. He concluded with implications of current research, stating, "… for railroads reasonably consistent evidence shows fairly strong economies of density and suggests constant returns to size, especially for large railroads" and described needed research into cost complementarities (later provided by McCullough and Ivaldi).

Gomez-Ibanez (1999, 99-136), of the Kennedy School of Government (Harvard University), provided a comprehensive review of modern pricing theory and its complications. He recognized a key insight of John Meyer. "The characteristics that complicate transport pricing and drive transport activities into the public sector are real, but they are often exaggerated. … Interest groups seeking to justify low prices, cross-subsidies, and other policies have incentives to overstate the difficulties in allocating costs or the degree to which marginal costs fall short of average costs." In regard to marginal costs, "Note the marginal cost has two components — an average cost per user, plus the change in average cost from serving an additional user." In regard to congestion externalities and tolls, "As a practical matter, pricing is more fungible than capacity expansion; thus it would be the natural instrument for policymakers to use to optimize infrastructure use. Unfortunately, policymakers often find raising prices politically more controversial than spending more money on infrastructure capacity, so Americans frequently enjoy more capacity and lower prices than would be optimal. … Many of these complications disappear when the same company operates all the vehicles using the facility… Railroads are a prime example… In such cases there is no congestion externality because the delays of adding an extra train to the schedule are internal to the company and its customers. The railroad does have to worry about the optimal mix of inputs — train sets, train crews, track infrastructure, and so forth — but that becomes a standard exercise in finding the cost-minimizing input mix and plant size for a firm. And the basic marginal cost rule equation (4-2) applies for pricing the railroad's services." He disputed the common assumption of that infrastructure leads to economies of scale. "In general, economies of scale in the right-of-way are diminished by the rich technological options available both within and among modes of transportation." A review of highway costs and pricing found serious undercharging of heavy trucks. "… many of the potential efficiency gains from correctly pricing highway infrastructure are lost." Ibanez stated that transportation infrastructure costs may appear more sunk in the short run than they really are: "however, congestion may be higher, capacity less lumpy, and sunk costs smaller than they first appear, with the result that short-run marginal cost may not be so different from long-run marginal cost and marginal cost pricing not so inconsistent with long-run cost recovery." In his summary Ibanez warned the reader to "beware of arguments that marginal costs are very different from average costs."

Gallamore (1999, 459-529) of Northwestern University illuminated the relationship between deregulation and innovation in the rail industry. He used time series analysis to demonstrate the effects of deregulation and presented theories on why inefficiency results from regulation in the transportation industry. He connected the financial resurgence with technological innovation. "The railroad industry's financial resurgence since the Staggers Act has had a powerful impact on the diffusion of technology. It is long and well established in economics that the predominant way in which new technology is diffused through an industry is by its embodiment in new capital goods, something that occurs much more rapidly when an industry is profitable and growing than when it is stagnant. The Staggers Act fed a financial recovery in railroading that not only permitted reinvestment (from current cash flows), but made it look smart (from a financial viewpoint)." Gallamore also connected the change in technology with changes in maintenance practices. "Moreover, there is an incentive to build stronger track structure for a densely used line so that maintenance-of-way crews do not have to return to it for rehabilitation for a longer time. Lighter maintenance, such as grinding and profiling, can be carried out intermittently, but taking track out of service for rebuilding has a high opportunity cost when traffic is heavy."

Bitzan (1999) of North Dakota State University found that railroads were natural monopolies over a fixed network size and that STB efforts to maintain competition in the face of mergers was not justified by railroad cost considerations. He found that that railroads were not natural monopolies over multiple markets and that there may not be a cost justification for further end-to-end mergers. His analysis employed a multi-product model and tested for cost subadditivity over multiple markets.

Judge (1999) illustrated how newer maintenance of way equipment was safer and more efficient than earlier technology.

Bitzan (2000) expanded on his previous work in a study funded by the Federal Railroad Administration. He examined cost subadditivity when (1) network size was held constant (e.g., parallel mergers), (2) while network size was expanded (e.g., end to end mergers), and (3) when costs of maintenance of way and structures were eliminated (e.g., open access operations). For all two-firm combinations, when network size was held constant, he found strict cost subadditivity, and that the average increase in costs for duplicate service would be over 40 percent. "Thus it is clear that Class I railroads are natural monopolies over a fixed network size." In the case of end-to-end mergers, he found strict cost subadditivity in only 2.9 percent of the observations (simulations), with monopoly costs lower than the two-firm costs only 13 percent of the time. "This suggests that further end to end mergers may not be beneficial." In the case of single firm and two firm costs operating over a single network, he found that 95 percent of all simulations indicate monopoly costs were lower than two-firm costs, and the condition of subadditivity was met more than 60 percent of the time. "Costs would increase in cases of total open access, or in cases of introducing competition to bottleneck segments." Bitzan cited Ivaldi and McCullough's work on density and integration effects published in 1999 at an IDEI seminar and later published in 2001. Bitzan also found economies associated with vertically integrated roadway maintenance and transportation.

Hariton and Milne (2000), in a report commission by the Canada Transportation Act Review, compared the competitive situations faced by rail and telecommunications. "While rail and telecommunications are similar in that they are network industries, they do differ as to demand characteristics and cost structure. These differences have implications as to the role of open access in promoting competition in each industry. … Rail transport is dominated by a small number of large shippers. In telecommunications, there is also a number of large customers. However, the bulk of the long distance market is a mass market, made up of millions of residential and small business users. … As a result, access can be expected to be more of an obstacle to competition in telecommunications than in rail. Large customers in either industry are attractive targets for competitors, who may provide alternative access agreements. As well, a large customer may supply his own access, to the network of his choice. However, rail does not serve the very large number of small customers with their low levels of traffic that telecommunications does. … Both enjoy economies of scale. However, it would seem that these economies of scale are much larger in telecommunications than in rail transport. … In conclusion, access is a more severe bottleneck in telecommunications than in rail transport, both because of diffuse demand and more significant economies of scale in the former" (Ibid, 32-33).

Dennis (2001), an economist at AAR, found that railroad productivity (cost savings, heavier ladings, and increased shipment size) accounted for 90% of the reduction in railroad rates since the Staggers Act. Only about 10% of the rate reduction were accounted for by changes in railroad traffic characteristics, such as an increasing percentage of bulk commodities, increased length of haul, and increased private ownership of equipment. He examined the changes in individual commodity characteristics (i.e., length of haul, weight, car ownership, railroad cost, truck transport cost) and compared them with changes in revenue per ton-mile using regression techniques. In summary, he concluded that shippers saved nearly $28 billion per year (1996 dollars) in railroad revenue between 1982 and 1996.

Mercer Management Consulting found that shippers benefited from intense intramodal and intermodal competition and that railroad managers should find new sources of productivity. "Most of the low hanging fruit, however, has long since been harvested" (Randall and Harsh 2000, 10). Regarding capacity: "While most of the railroad network in North America presently has sufficient capacity to handle current and reasonably anticipated projected traffic flow, choke points do exists today and will inevitably emerge at other place in the system if the industry is successful in attracting new traffic. Most of the are located in urban areas and terminals. Choke points can be addressed by investing in additional capacity or by improving utilization of existing assets. … Providing that the railroads operate in a regulatory and commercial environment that permits them to continue to attract sufficient capital and skilled management, we see no reason for them not to continue to address choke points as they develop" (Ibid, 12).

McCullough and Ivaldi (2001) investigated cost complementarities between infrastructure and different operational outputs in the U.S. rail industry. They found strong complementarities between operational outputs (i.e., bulk, intermodal and general freight operations), but not between operations and infrastructure. "We propose an alternative approach based on the observation that on mature rail networks most infrastructure related activity is aimed at maintaining the capacity of the existing network rather then for expansion. In 1996, for example, U.S. railroads installed 14.3 million ties and 840,000 tons of rail, according to the annual Analysis of Class I Railroads published by the AAR. Some 13.4 million ties (94.25%) and 803,308 tons of rail (95.6%) were for 'replacement' rather than for 'addition', according to the AAR. In this respect, maintenance behavior on the rail network is similar to that on mature highway systems where each additional vehicle mile imposes a variable maintenance cost because it moves forward in time the point at which the infrastructure must be rehabilitated. Rather than defining way and structures costs as fixed costs, which by definition do not respond directly to changes in output levels, we view maintenance activity on a mature network as a variable output which imposes costs directly and which interacts directly with other outputs. We use 'ties laid-in-replacement' from the AAR's Analysis as a measure of output for the infrastructure maintenance entities within each firm" (Ibid, 165). "The overall return to network density for the U.S. freight railroad industry is derived… estimated at the mean of out data is 1.65 (with a standard error of 0.15). … A 1% increase in the level of activity controlled by a single firm would generate variable cost increases of about 0.61%." This finding was consistent with earlier studies on returns to density by Keeler (1974) 1.79, Harris (1975) 1.72, Harmatuck (1979) 1.92, Caves et al. (1985) 1.76, Berndt et al. (1993) 1.56, Wilson (2000) 1.31.

Hamberger (President AAR) reflected on the historical effects of constrained rail capital (U.S. Congress House Committee 2001, 30). "History has taught us, Mr. Chairman, what happens when railroad capital needs are not met. During the 1970s, every major railroad in the northeast, as well as several in the midwest, were thrown into bankruptcy. Rail infrastructure suffered enormously because of lack of capital, and by 1976, 47,000 route miles were bring operated under slow orders because of dangerous conditions. … Fortunately the Staggers rail Act changed all that. By freeing railroads from antiquated regulation, Staggers gave railroads the opportunity to earn revenues sufficient to cover their cost of operation and to reinvest both in equipment and infrastructure. … Unlike other transportation modes, railroads rely overwhelmingly on private financing — not Government funds — to pay for infrastructure and equipment. This means the major freight railroads must earn enough year after year to internally generate investment funds and to attract capital market funds. Access to capital will remain critically important in the future as demand for freight grows. … Anything that threatens the railroad industry's ability to generate capital internally or to attract capital in the capital markets will in fact threaten future expansion of rail capacity" (Ibid, 30). "There is a direct correlation between the amount of money that is invested and safe operations" (Ibid, 36). Hamberger also discussed the problems with the proposed legislation that would force freight railroads to accommodate passenger services, and the problems of mixing passenger and freight operations (Ibid, 37-41). "However, the industry's internal cash flow is not sufficient to sustain the capital investment railroads require, so railroads must access the outside capital markets every year. From 1981 to 2000, approximately 63 percent of Class I railroads' capital expenditures was provided from internally generated funds and 37 percent from external capital providers. The 'funds shortfall' over this period was nearly $32 billion, highlighting both the importance that access to outside capital has to the railroad industry and the dangers that would be involved if access was threatened by short-sighted legislation or other means. … The rail industry's limited ability to fund infrastructure investment from earnings is a reflection of the historically low profitability of the industry. U.S. freight railroads have consistently failed to earn their cost of capital, and rail profitability consistently ranks in the bottom quartile of all U.S. industries" (Ibid, 89-90). "Railroads must be able to offer investors returns comparable to what the investors could expect if they invested their funds elsewhere at comparable risk. As one Wall Street analyst recently stated "Capital flows to areas of highest return. If … new regulations change the rules of the game and ensure poor returns, then the Street will disinvest (or further disinvest), causing management to begin to reallocate cash and begin 'harvesting' the business. They will have no choice" (Ibid, 97-98).

Warfel (Chairman of the Railroad Transportation Committee of the National Industrial Transportation League) presented the shipper viewpoint of rail investment problems (U.S. Congress House Committee 2001, 34-5). "One of the principal reasons for the railroad's overall reluctance to continue capital spending at the levels seen in the late 1990s is the pressure from Wall Street analysts and their institutional investors. These folks are far more interested in maximizing the return on past investments than worrying about capacity constraints that may appear five to ten years from now. Despite Wall Street's next quarter's earning approach to the railroad business, we firmly believe that the Nation's railroads need to begin spending now to upgrade their properties and expand their capacity to handle future increases in traffic. Recent DOT estimates call for a doubling of freight traffic in this country by the year 2020. … So how do we prepare the railroads to accept this increased volume of traffic? The League feels there are five possible solutions that warrant consideration. First, information technology, such as the use of Positive Train Control, could enable the railroads to expand capacity without having to add track. Second, rail system traffic flows could be redesigned to avoid terminal areas perhaps by making up trains that bypass as many intermediate terminals as possible. Third, shippers should be granted improved access to other rail carriers either within terminal areas or to the nearest physical interchange with another carrier. Fourth, paper barriers that prevent short line railroads from offering their online shippers access to non-congested railroads should be eliminated. Finally, although the League has not officially endorsed the concept yet, the possibility of using public funds for certain nationally critical rail capacity improvement projects should be examined" (Ibid, 34-35).

Warfel described the emergence of capacity constraints. "… it appears that the rail system is beginning to reach some capacity constraints, because the system appears to unduly affected by internal and external 'shocks'. Internal shocks include rail mergers, which have fairly consistently thrown the rail system into major disarray. External shocks include such things as weather-related events. Moreover, the recent past in the economy's growth may be concealing difficulties in the rail system's capacity to handle 'peak' traffic periods, generally each from the late Summer to the end of November. In our view, the rail system appears to have increasingly little 'give', or flexibility, to handle these internal and external events, especially when a weather event such as a hurricane occurs in a peak period. This situation, in turn, suggests to us that the rail system is beginning to approach some limits on its ability to effectively handle new traffic growth."

"The railroads have poured heavy investment dollars into their systems, including improvements related to the mergers of the past decade. According to the testimony of the BNSF's CEO **Matt Rose**, in a recent hearing of the Senate Commerce Committee, industry investment peaked in 1998 at $7.4 billion. However the level of investment appears to be tapering off. Mr. Rose estimated Class I railroads' invested amount $5 billion in 2001. Another witness at the Senate hearing, Dr. Alan Zarembski of Zeta-Tech, estimated that the railroads needed to invest $8 billion per year, simply to maintain their systems in their current condition."

"One reason for the dropoff in investment seems to be pressure from Wall Street analysts and their investors who are anxious to see quicker returns from the investments of the past, and who would rather see the rail system be capacity restricted so that the railroads can better dictate the price of their service, leading to higher rates, higher revenues, and higher returns on invested capital" (Ibid, 145).

"On the other hand, there are constraints facing the railroads in their ability to finance the capacity improvements necessary to handle the increased traffic we want them to carry. Wall Street's short term outlook is inconsistent with long term public needs for an adequate transportation structure. This outlook hits the railroad industry the hardest of all, because the entire industry, unlike all other transportation industries, is privately financed" (Ibid, 146).

The Canadian Minister of Transport conducted a review of railway track access pricing as required by the Canadian Transportation Act (Kieran Management 2001). The report described economic principles and costing methods for Europe, the U.S., and Canada, along with economic cost factors to be considered. "Marginal Cost Components can include: Operating costs, Infrastructure damage costs (maintenance costs, wear and tear of the infrastructure, reflected by such as resurfacing of roads, rails and runways) … Important parameters in the determination of rail capacity over a period of time can include the following: Speed Limits, Distribution of train speeds and priorities, Siding spacing (single track) and siding capacity relative to train length and distribution of siding lengths, proportion of multiple tracks, crossover spacing, signal block spacing, train characteristics, traffic peaking and directional imbalance, and incidents of disruption." Cost of capital is discussed. "a middle ground of 15% is used to develop the base cases in this report."

Stagl (2001) described how maintenance blitzes were used to avoid track downtime. He also found that year to year variation in railroad expense and investment budgets can be significant.

Allen et al. (2002) described changes in the ownership of regional and short lines since the Staggers Act. "Including trackage rights, the Class Is operate 122,186 miles, the regionals 20,978 miles, the locals 21,512 miles, and terminal and switching companies 7,425. … Prior to 1980, there were a number of Ma and Pa owners in the business. … Certain industries invested in railroads as part of the vertical integration in their industries… Cities, counties, states and port authorities owned railroads as part of their industrial development strategies. Terminal switching companies were jointly owned by Class I carriers (or by a city/port authority) to provide unbiased railroad access to all customers and interchange among railroads in a metropolitan area. … In general, however, the image of the industry was one of Ma and Pa operations. … All of the above exist today as owners today… but by far the leading fuel of the growth since 1980 has been the entry of holding companies that own multiple railroads. … Of the approximately 48,000 non-class I miles today, about 31,000 are controlled by or are affiliated with entities that control two or more U.S. railroads. Eighty-one entities control 341 of the approximately 574 regional and short line carriers. … Prior to 1984, there were very few regional carriers. From 1984 to 1993, the formation of regional railroads was one of the big stories in short lines. … Of the new railroads started in this period, governments owned 15.4%, the original carrier owned 8.9%, while the short line railroads owned 73%. … In the 1993-1997 period, Due and Leever note the growth of sub-regional railroads, i.e., those with track between 150 and 400 interconnected miles and continued growth of short line holding companies. Only two regional were formed in this period. Governments owned 14.9%, the abandoning railroads owned 15.2%, and the short lines and regional railroads owned 69%. Of the short line and regional railroad owned miles, 85% were owned by the short line railroad holding companies. Shippers only accounted for 2.8% of the total new mileage" (Ibid, 78-80).

Hausman and Myers (2002) of MIT evaluated the effects of sunk cost and asymmetric risk in the application of contestable market policy to regulate dominant freight movements. Specifically, they demonstrated that when evaluating "equilibrium" rates for Stand Alone Costs, the STB undervalues the actual capital return required for a potential new entrant in application of contestable market theory. This under-valuation comes about as a result of the asymmetric risks that face railroads as a result of significant sunk costs. Hausman applied a Real Options Approach to demonstrate the degree to which equilibrium capital return is understated, which he calculates as 40% understated in a recent SARR case (UPRR vs. FMC). Hausman stated that the result of the miscalculation resulted in a finding for the shipper when it would have otherwise decided in favor of the railroad (in the FMC case). He demonstrated that the railroad industry was reasonably risky, and observed that the gap between actual and necessary rate of return for U.S. Railroads had been steadily widening since 1989.

The International Union of Railways (2002) conducted a study that was sponsored by the UiC Infrastructure Commission in June 2002. The report stated that enhanced renewal activity reduced maintenance cost but did not quantify those findings.

Standard & Poor's (2002) rated railroad stocks according to certain factors including regulatory environment and business risk. One key measure was Earnings Protection "EBIT [Earnings before interest and taxes] divided by interest". Another was cash flow adequacy: "Cash flow in relation to cash needed for capital expenditures, debt maturities, and dividends often provides a better picture of near-term financial health and credit strength than earnings measures. … Cash flow in relation to capital expenditures: Funds flow divided by capital expenditures, funds flow in relation to committed and probable capital expenditures, estimated maintenance level of capital expenditures, timing of capital spending in relation to the economic cycle and cash flow benefits of large capital projects."

The **American Association of State Highway and Transportation Officials** (2002) issued a study of the future capacity requirements and alternatives facing the U.S. freight transportation system. The report expressed concerns about the freight rail system's ability to handle future needs: "the (railroad) productivity gains and competitive rates have not been sufficient to rebuild market share and increase revenue. Railroad revenues continue to drop. The industry's return on investment has improved from about 4 percent in 1980 to about 8 percent in 2000; however, it is still below capital at 10 percent. Most of the benefits of railroad reorganization and productivity improvements have accrued to shippers and the economy in the form of rate cuts, rather than to the railroads and their investors. … This is a major problem for the railroad industry because it is extraordinarily capital-intensive. Railroads spend about five times more to maintain rail lines and equipment than the average U.S. manufacturing industry spends on plant and equipment. Wary of the gap between the railroads' capital needs and their income, investors have backed away from railroad stocks. … The rail industry today is stable, productive, and competitive, with enough business and profit to operate but not to replenish its infrastructure quickly or row rapidly. Market forces will continue to pressure the rail industry to streamline and downsize, to maximize revenues, and to minimize capital costs." The report provided four investment scenarios: (1) No Growth – minimal Class I investments from revenue alone resulting in the same volume of freight in 2020 as 2002 – would shift 900 million tons of freight, 31 billion truck VMT to highways at a cost to shippers of $326 billion, cost highway users $492 billion, and add $21 billion to highway costs over 20 years. (2) Constrained Investment – what the Class Is can afford today from their revenue plus borrowing resulting in additional freight but still loose half share – would shift 450 million tons of freight, 15 billion truck VMT to highways at a cost to shippers of $162 billion, cost highway users $238 billion, and add $10 billion to highway costs over 20 years. (3) Base Case – higher level of investment to maintain current share – with funding coming from railroad investment and public-sector participation. (4) Aggressive Investment – would increase its share of traffic and reduce burden on highway system – funding from railroad investment and public sector participation – shift 600 million tons of freight and 25 billion truck VMT off highways, save shippers $239 billion, save highway users $397 billion, and reduce highway costs by $17 billion" (Ibid, 2-3).

The report stated that railroads' stock market value compared to the S&P 500 was one fifth of its 1980 size (Ibid, 36). "A market driven evolution of the freight rail system will accommodate some of the economic growth, but relieve little of the forecast congestion on the highway system. A public policy driven expansion of the freight rail system supported by public sector investment is needed if the system is to maintain its share of forecast tonnage and help relieve pressure on the highway system. Without coordinated public ands private action, congestion and capacity constraints will weaken the freight industry, the economy, local communities, and the environment. … A first approximation suggests that the freight-rail system needs an additional investment of $2.6 billion to $4 billion annually. This investment can be shared among the railroads, the states, and the federal government, and portions of the public sector's investment could be paid pack from long-term growth in the railroads' revenues" (Ibid, 80). "To increase profitability, and to adapt to capital and capacity constraints, railroads are examining market segments not just for their contribution, but for their lost opportunity costs as well, and are de-marketing the least attractive traffic. Some carriers are considering not only the elimination of unprofitable branch lines, but possible whole lines of business, and in both cases the carload traffic is the prominent target. There may be serious concerns for states that maintain short line systems…" (Ibid, 92). In suggesting financing strategies for new investment the report made the following recommendations: (1) Direct funding out of railroad revenues, (2) Rail user fees or surcharges, (3) Direct Federal Appropriations and Earmarks, (4) Congestion Mitigation (CMAQ) grants, TIFIA loans, Railroad rehabilitation -(RRIF) loans, Grade crossing funds, Federal Tax-Credit Bond-Financing programs, Issuance of Tax Exempt Debt for Railroad Infrastructure, Use of Rail-Share of Gas Tax for Trust Fund, State Based Loans, Sale of Freight Assets for Rail Passenger Use, Relief from State Property Taxes on Rail (Ibid, 100-101). It is significant to note that report never listed as a possible strategy the imposition of fully allocated costs on truck freight transportation, or the reduction of regulatory limits on rail pricing.

Mancuso and Reverberi (2003) used a translog short-run variable cost function to analyze the Italian railway company (FS) using data from 1980 to 1995. They found that the translog function provided a good approximation of FS technology, production factor demands were inelastic and that the railroad had limited ability to substitute between inputs, and that it operated at diseconomies of scale. The study suggested that the railways either invest in more capacity or run fewer trains. It also stated that rail service in Italy would not be a natural monopoly in the absence of regulation, with the evolution of specialized small services. They stated that infrastructure investment is non-optimal. "… adequate incentives should be provided to ensure that investment is at an optimum level. In this framework, the application of marginal cost pricing will fall short of covering total infrastructure costs by as much as 40% or more, so that a range of options should be devised, from full public subsidy to various charging systems that do cover total costs with a lesser degree of efficiency in terms of infrastructure fares. … Due to the high level of travel demand, infrastructure investment to expand the current capacity are recommended on primary routes as a main remedy to congestion problems."

Flower (2003a), managing director at Salomon Smith Barney, reflected on the financial dilemma facing U.S. railroads with respect to intermodal business. "The key concern is that intermodal historically has garnered railroads a much lower profit margin. … one of the lowest average margins — in the 10 percent to 20 percent range. … the rail industry is notorious for not earning its cost of capital, and there are no guarantees that significant amounts of public/private funding will be made available … several industry participants have indicated that additional capital investment in railroads' intermodal networks is needed in order to make rail operations even more fluid…"

Flower (2003b) also described capital discipline as a new strategy for at least one major railroad. "Avoiding one-size-fits-all approach, Davidson and President/Chief Operating Officer Ike Evans continue to stay the yield strategy course, focusing on improving asset use, capital discipline, productivity, pricing and service-product introductions to supplement revenue growth. UP appears much more focused — the railroad is not seeking to be all things to all customers — helping to firm pricing in the western rail marketplace. However, we believe this shouldn't be interpreted as an opportunity for the western roads to try and over-exert any realistic pricing opportunities, which could lead to unintended regulatory and/or competitive developments. … On a final note, we again return to out mantra that, as the economy improves, UP must retain very tight control of capital spending and not become lured into aggressively pursuing growth that necessitates a notable capital expenditure increase. Getting caught up in expanding an asset base to chase growth often can be a difficult strategy for a rail industry concern. We believe that UP management will retain the discipline to facilitate growth, but not over capitalize in an attempt to capture growth that might not make long-term sustainable sense."

Keane (2003) pointed out that the opinion of political officials towards railroads was poor. Sen. Conrad Burns (R-Mont) stated, "The wheat producers in my state farm one year out of three for the railroad, and that's flatly wrong. … If we don't take responsibility for something that our shippers have no control over, then I think if there's a monopoly, we take control over it." Sen. Jay Rockefeller (D-W.V.) stated, "What we hope to convince our colleagues of is that the STB has been asleep at the switch. The agency has done nothing, and Congress has done nothing to focus the agency's energies, while the railroads industry has enacted a business model that would do justice to the old Soviet Union, unfettered and inefficient monopolies providing bad service with customers left no other choice but to pay whatever the railroads demand."

Tom Haley, (2003, II-54-55) Union Pacific's Assistant Vice President Network and Capital Planning, provided expert testimony that illustrated how railroads calibrate their investment to accommodate incremental traffic increases through incremental capacity improvements in "Arizona Electric Power Cooperative, Inv., v. The Burlington Northern and Santa Fe Railway Company and Union Pacific Railroad Company: Joint Variable Cost Rebuttal Evidence."

The **Australian Government Bureau of Transport and Regional Economics** (2003) demonstrated how higher track investment could reduce maintenance costs and conversely how low-quality (i.e., through low investment) track could support high axle loads with a high maintenance expense.

CitiGroup/Smith Barney issued a report on railroad capital expenditures titled "Zen and the Art of Railroad Management" (Flower et al. 2003). "Investment continues to be more weighted toward the road infrastructure. We believe that rail capital spending has become increasingly efficient in recent years." The report divides investment and cash flow trends into period before and after 1997. "Aggregate industry capex is expected to be relatively flat in 2003. … We prefer to see capex growing at a rate that is more in line with GTMs … The gap between the two measures (GTM and capex) is likely to narrow as traffic growth is likely to rebound with the economy. … Being a 'growth' railroad is simply not a terribly sound business or investment strategy for a rail company seeking to drive improving ROIC (Return On Invested Capital) and stock performance."

Swier (2004 34-36) stated that the appropriate combination of renewal and maintenance practices had a direct influence on the financial performance of railway.

A **Bear Sterns** Equity Research report stated that "a modest rise in capital expenditures that drove net income growth could be a positive for the rail stocks even if this capital expenditure rise caused free cash generation to remain flat" (Wolfe et al. 2004, 10). "Following its acquisition, NSC had comparatively greater leverage than most of the other rails, which may have been a factor in its relative capital discipline after the joint acquisition of Conrail with CSX" (Ibid, 16). "Should traffic density continue to improve, this could cause constraints on the rail infrastructure at some point in the future. Such a scenario could precipitate an acceleration in overall infrastructure spending" (Ibid, 19). "During our analysis period (1990-2003), the major U.S. railroads experienced significant volatility in their free cash generation. … For the group, capital spending tends to have greater volatility then cash from operations. As a result, changes in capital expenditure are the most important driver of free cash flow for the rail industry overall" (Ibid, 31). "The eastern rails both spend a noticeably lower percentage of revenue on capital over the analysis period we shoe from 1996 through 2003, with average spending for these two rails in a range of 13% - 15% of revenue. … Our sense is that the relatively greater capital intensity (as a function of revenues) is a meaningful factor that works against the western U.S. rails in terms of free cash margin" (Ibid, 35). "The replacement cost of these long-lived assets is well above the original purchase price of the asset being replaced, which drives capital spending well above depreciation on a sustained basis" (Ibid, 35). "… large negative working capital swings that were mostly recorded in both 2001 and 2002 (for UP). .." (Ibid, 97).

Tony Hatch (2004) described current issues concerning railroad capital expenditures. " 'Service issues cloud bright rail prospects.' We've all head that one before. One difference between this most recent rail network congestion problem and the post-merger late '90's crisis – aside, I hope, from the severity – is the question of capital. Today, the whisper is: Did the rails spend enough? Is this congestion problem an issue of capacity, beyond that of crews and forecasting? Rail 'capex' is never far from the investors' minds, nor that of rail managers, but only in times of trouble do shippers, regulators, Congressfolk and lobbyists give it its due. Anticipating golden years of growth rather than the consolidation blues, rails in the 1990's spent, spent, spent – peaking in 1999 at more than $7 billion, or more than one dollar of revenue in every five, excluding leases. … To be fair, railroads' history of almost never earning their cost of capital — the criteria by which any and all business must be judged — is hard for the financial community to ignore. … Capex to come. To that end, railroads are putting money in intermodal, locomotives and technology. In the future, spending will trail opportunity and shortages will occur because investors will demand a little "show me" before they open up the purse. … capex will increase in measured steps as rail narrow that all important capital gap…"

Hensel (2004) described the congestion problems of railroads in 2004. "Union Pacific's rail lines are again congested, meaning considerably higher costs for shippers forced to seek out alternatives. … Houston based Lyondell Chemical said Thursday the railroad's congestion this year could cost it millions of dollars. … 'We have shifted in some instances to truck transportation to meet those (customer) needs and that is a dramatic increase in costs. … So what would normally be 10 days is now more than 15. … There will be a long-term impact on the regional economy.' Union Pacific, in its letters to customers, said it was making projections based on what it was being told. One large customer said to plan on an increase of 6 percent for this year, but shipments are up 19 percent. There are many similar examples in all of our business groups where demand was several times higher than predicted."

David Goode, CEO of Norfolk Southern, described the prevailing attitude of the investment community towards railroads at the North American Rail Shippers conference (Gallagher 2004). "This is the strongest demand for rail service that I've seen in my 35 years in the rail industry. I've seen it strong in particular commodity areas, like coal, but never across all businesses like I've seen it today. And all of the indicators — a recovering economy, chronic highway congestion, and emphasis on public safety — suggest that this demand will be with us for a long time. The way we handle it is to be innovative and make investments." Raising the money to make those investments is difficult, Goode said, because railroads are under serious investor pressure. "(NS) has had the best back-to-back (financial) quarters in seven years and the stock market has absolutely yawned. That says nothing so much about NS but the attitude toward our industry as one that can't meet its cost of capital."

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Curriculum Vita

George Avery Grimes

B.S., University of Illinois at Urbana-Champaign, 1978
M.S., University of Nebraska at Lincoln, 1994

Expertise:

Railroad Operations, Engineering, Finance, Information Systems, Environmental Management, Emergency Response and Transportation Safety

Education:

University of Illinois, 2002-2004, Ph.D. Candidate (engineering/economics/finance)
University of Nebraska, Lincoln, NE, (1991-1994) MSCE (environmental, business)
University of Nebraska, Omaha, NE (1989-1991) MBA program
St. Louis University, St Louis, MO (1982-1984) MBA program
University of Illinois, Urbana, IL, BSCE (transportation/railroads) 1972-1977

Licenses:

Professional Engineer - Missouri (E20516) 1982; Washington (22682) 1985

Affiliations:

American Railway Engineering and Maintenance Association (AREMA)
    Committee 13 (Environmental Engineering)
    Committee 16 (Engineering Economics)
Transportation Research Forum

Personal:

Date of Birth: April 8, 1954 Birthplace: Frankfurt, West Germany Citizenship: USA
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Professional History:

Mr. Grimes has over 31 years of experience in the transportation industry, including operations, engineering, finance, information systems, environmental management, emergency response, safety and security issues.

(2002 to Present) Private Consultant
Railroad engineering research for the United Kingdom, railroad risk analysis for Mexican railroads, security guidelines for hazardous materials shippers.

(2002 to Present) University of Illinois at Urbana-Champaign, Department of Civil and Environmental Engineering, Railroad Engineering Program
Primary research concerns the nature of railway investment from the collective viewpoints of engineering, economic, and financial theory. Central thesis is that railway cost methodologies miscalculate the actual marginal cost of investment thereby leading to sub-optimal pricing decisions. Responsibilities also included assisting and supervising students on railway engineering research projects, and providing guest lectures in railway engineering classes and seminars.

(1999 to 2002) University of Denver, Intermodal Transportation Institute
Responsible for graduate program lectures on Transportation Economics, Safety and Human Factors, and Research Methods (adjunct faculty).

(1998 to 2002) Center for Toxicology, Director Division of Railroad Operations
Responsible for emergency response planning and response, environmental management policy and planning, transportation risk analysis, railroad operations and economics consulting, and other services specializing in this industry.

(1996 to 1998) Dames & Moore Group, Director of Railroad Services
Responsible for developing opportunities in the railroad industry including environmental services, engineering services, information systems development and implementation, emergency response services.

(1990 to 1995) Union Pacific Railroad, Director Environmental Operations
(California, Oregon, Washington, Idaho, Nevada, Utah, Montana, Wyoming, Colorado, Iowa, Nebraska, Missouri, Kansas, Oklahoma, Texas, Arkansas, Wyoming).
Responsible for management of operating and capital budgets; management of professional and field staff distributed over region; policy development/implementation; all compliance and operating activities related to wastewater, storm water, hazardous waste, air; emergency response activities.

(1987 to 1990) Union Pacific Railroad, Director Service/Transportation Measurements
Responsible for development of system-wide measurements for the operating departments, including customer commitments, service performance, train performance, operating unit budget performance, safety measurements, unit train operations, intermodal operations, identification of process failures and process analysis. Responsible for development and negotiation of service measurement standards with customers.

(1986 to 1987) Union Pacific Railroad, Director of Engineering
Responsible for planning and administration of engineering functions in the Central Region, including management of work order program management, equipment and supply requirements, manpower planning, contract negotiation and auditing, labor management, claims handling.

(1984 to 1986) Union Pacific Railroad, Manager of Budgets
Responsible for financial and asset management of the operating department in the Northwest District, including development of new cost and budgeting systems, development of operating budget projections, cost control, personal injury accident analysis, and capital program administration.

(1978 to 1984) Missouri Pacific Railroad, Senior Transportation Planner
Responsible for general support of senior transportation staff, including design of train systems, rate litigation testimony defense, capital improvement studies, operating efficiency studies, accident investigation, personal injury studies, equipment requirements, train mile budgets, and various other senior management requests.

(1976 to 1978) City of Champaign Engineering Dept., Assistant Engineer
Responsible for municipal capital and operating improvement studies, including streets, bikeways, sidewalks, storm and sanitary sewers, street lighting, fire station and emergency response facilities. Performed field engineering duties and served as liaison to City Counsel.

(1975 to 1976) Champaign-Urbana Mass Transit District, Manager Operations
Responsible for direct management of municipal mass transit system, including labor relations, day to day system operating performance, collection of revenues, operating studies, driver training, customer complaint handling, accident investigation.

(1973 to 1975) Chicago Transit Authority, Assistant Engineer
Responsible for assistance with capital improvement programs, field engineering studies, railroad/highway grade crossing studies, park-and-ride capital improvement studies.

Publications:

- Grimes and Watson. 2001. *Recognizing & Managing Carrier Security: A Handbook for Hazardous Material Transporters.* Denver, CO: Freberg Environmental Insurance
- Grimes and Milner. 2000. Toxicology for Emergency Responders. *Bureau of Explosives Hazardous Material Proceedings*
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- Grimes. 1994. *Waste Minimization Issues for the Railroad Industry*. Master's Thesis at University of Nebraska Lincoln
- Grimes. 1990. Customer Service Planning and Measurement. *Journal of the Transportation Research Forum*
- Grimes. 1982. Terminal Facility Operations and Unitrain Planning. *Journal of the Transportation Research Forum*
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