MARKET AND SOCIAL INVESTMENT AND DISINVESTMENT IN RAILROAD BRANCH LINES: EVALUATION PROCEDURES AND DECISION CRITERIA

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ABSTRACT

MARKET AND SOCIAL INVESTMENT AND DISINVESTMENT
IN RAILROAD BRANCH LINES:
EVALUATION PROCEDURES AND DECISION CRITERIA

By

Marc Anton Johnson

Collapse of the Penn Central Transportation Company and subsequent massive railroad line abandonment proposals have triggered unprecedented attention to railroad capital shortage problems developing for more than half a century. Recent federal policy actions, outlined in the Regional Rail Reorganization Act of 1973, have shifted a portion of the capital burden on lightly traveled branch lines to local communities and users of service. Railroad companies have new opportunities to evaluate branch line enterprises on the basis of market criteria. States and local communities have new responsibilities for public investment to continue railroad services with related nonmarket attributes.

This research is approached to fulfill two missions. One mission is to develop a framework for extended research on the role of various economic participants in structuring an active transportation policy for lightly traveled railroad branch lines. The second mission is to contribute to solution of the immediate problem of state governments, that of determining which lines to subsidize under provisions of the Regional Rail Reorganization Act. Specific purposes of this research are to determine railroad freight transportation market characteristics and to develop decision criteria and evaluation procedures for market and social investment and disinvestment in railroad branch lines.

The market bound to supply of branch line service is developed assuming railroad firms with existing facilities and long term profit maximizing objectives, with no administered restraints and no responsibility for external effects of resource use. A railroad investment planning model is developed incorporating a stock-flow railroad production function and acquisition and salvage alternatives for rail roadway capacity. Assuming constant railroad rates, application of the Kuhn-Tucker theorem provides necessary and sufficient conditions for optimal firm investment and disinvestment in small roadway segments. When the present value of future net revenue generated at a terminal station is less than or equal to the associated value in liquidation, the line will be sold to another entrepreneur or dismantled. When the latter value exceeds the former, a subsidy equal to the difference becomes necessary to encourage voluntary continuation of service. A procedure is developed to evaluate net revenues and liquidation values on particular line segments.

Preliminary application of the abandonment criterion is made to twenty-one Michigan line segments under ICC abandonment application from 1968 to 1972. Results suggest that railroads tend to seek abandonment not when opportunity losses appear, but only after operating deficits occur, revealing a tendency to maintain investments in rail roadway for periods extending beyond financial health of individual lines.

The assumption of predetermined railroad rates is relaxed to allow market conditions to influence railroad pricing policies. Conditions for local railroad price discrimination and collective user subsidy are developed and a rudimentary measure of revenue enhancement potential is designed to test the power of pricing policy in maintaining local branch operations.

Consideration of the market bound of demand is limited to developing statistical experience with hedonic transportation demand estimation. A model of derived demand for railroad freight service explicitly treats railroad and motor carrier service quality variables. Derived railroad service demand becomes a function of product price, production cost and effective prices of railroad and motor carrier services. Effective transport prices are defined as published rates plus other implicit costs associated with consuming modal services.

Empirical demand models are constructed to measure the influence of service quality variables upon total annual quantity of railroad service demanded and upon modal selection probability (modal split), holding influences of firm and shipment characteristics constant. Quality variables are selected on the basis of transportation market studies to control specification error; quality variables include speed, delay in equipment delivery, damage in transit and freight rates of rail and motor modes, and service reliability of railroads. Specification error tests based upon BLUS residuals reveal the log-linear functional form to be superior to the linear form for railroad service demand functions. The logit-linear form of modal selection probability functions is revealed to provide consistent estimates. Demand and modal selection probability estimates are made for outbound grain shipments and inbound fertilizer and feed shipments made by Michigan grain elevators and farm stores. Data are supplied from the Michigan Freight Transportation Survey conducted by the author for the Michigan Department of State Highways and Transportation.

Demand estimation supports previous evidence that commodity groups are differentially affected by service quality variables. Results also

support the contention that service quality affects traffic volumes upon which abandonment decisions are based. However, the magnitude of influence appears much less than that suggested by market research and testimony before ICC abandonment hearings.

The social bound to provision of branch line service encompasses both market recognized and external benefits and cost of investment. Legislative authorization for states and local communities to subsidize unprofitable lines limits the social bound to Pareto equilibria. Where discounted net operating revenues plus collectible external values exceed line liquidation value, branch line service lies within the social bound. Seven external effects of branch line abandonment are considered within a broad temporal and geographic frame. Nonmonetary impact indicators are developed for effects of line abandonment upon employment, fuel usage and highway service life. Also considered are impacts upon rents to local properties, consumer prices, the environment and latent consumers of service. Incidence of net effects suggests that local evaluation of public participation would tend to bias willingness to subsidize in excess of net social gains.

Decision criteria and evaluation procedures are applied to a two county area of central Michigan with the purpose of demonstrating use of these tools in branch line analysis. The area selected harbors representative intermodal and intramodal interactions of service availability with a complete highway system and two railroad lines of different companies. Revenue enhancement from local price discrimination is seen to potentially retrieve some marginal links from deficit. Opportunities to consolidate traffic on other company lines or to divert traffic to other stations of the abandoning company, depress the viability of individual rail links.

MARKET AND SOCIAL INVESTMENT AND DISINVESTMENT IN RAILROAD BRANCH LINES: EVALUATION PROCEDURES AND DECISION CRITERIA

By

Marc Anton Johnson

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A jewel for my family

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TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

SUBSIDIZING RAILROAD LINES: AN ANALYTICAL GAP

Collapse of the Penn Central Transportation Company and subsequent massive railroad line abandonment proposals triggered unprecedented attention to problems developing for more than half a century. Capital shortage has plagued the railroad industry since the Great Depression. Recent federal policy actions have shifted a portion of the capital burden on lines with light traffic density to users of services or collectives of users. Railroad companies have new opportunities to evaluate lines on the basis of market criteria. States and communities have new opportunities for public investment to provide services with related nonmarket attributes.

The research reported here has been approached to compromise two opposing missions. One mission has been to develop a framework for extended research on the role of various economic participants in structuring an active transportation policy for lightly traveled railroad lines. The second mission has been to contribute to solution of the immediate problem of state governments, that of determining which lines to subsidize under provisions of the Regional Rail Reorganization Act. The two missions have revealed themselves to be much more complementary than at first thought. Sketches of the economic and institutional environments of railroading and major emphasis upon economic theory as a deductive guide dominate this initial research. Empirical applications are rudimentary and each individual topic is rich with opportunity for methodological refinement. Empirical work has been approached with extreme care to create realistic impressions for those who may use these results.

The particular purposes of this research are to determine railroad freight transportation market characteristics and to develop market and social investment and disinvestment criteria for railroad branch lines. Markets are typically characterized by technical and behavioral boundary functions separating feasible and infeasible or rational and irrational actions. Economic criteria are described by particular points on these boundary functions. Long run demand and production-investment considerations are used to establish the market bound to provision of railroad service. A long run excess cost relationship provides a means to measure magnitudes of subsidy necessary to encourage retention of service levels deviating from partial market equilibria. Social demand and cost functions establish the social bound to provision of railroad service.

The bankruptcy and abandonment plans of the Penn Central Railroad shocked Michigan. Nearly a third of Michigan's lines are owned and operated by the Penn Central. An active abandonment program by the Chesapeake and Ohio Railroad, bankruptcy of the Ann Arbor Railroad and failures of Lake Michigan ferry services added to state concerns. In view of these concerns, the Michigan Public Service Commission, in their session of December 22, 1972, ordered each railroad company owning or operating lines in the state of Michigan to appear for a hearing. The order included a written response to a questionnaire and appearance before a hearing examiner for a nonadversary examination. The Commission's purpose was "to apprise itself of the present situation and problems in and about the state of railroads and railroading in the State of Michigan, and to become more informed as to the future of railroads and railroading in the State."[1]

During the hearings, conducted during February and March, 1973, the major railroads operating in the state rebuked abandonment review procedures practiced by the Commission. The railroads interpreted existing state policy as opposition to all abandonment activity except for infrequent nonintervention in the clearest cases of line failure. To the railroads, abandonment review procedures of the state appeared inconsistent and lacking in basic guidelines.

By June, 1973, the complexion of the Regional Rail Reorganization Act was unfolding. Basic in several proposals was facilitated rationalization of railroad properties with options for states, communities and shipper groups to salvage unprofitable lines by subsidy or purchase. The Governor of Michigan established an Interagency Task Force on Railroad Needs, in June. The Task Force was to determine which railroad lines were essential for Michigan commerce and future development. An investigatory branch of the Task Force was established in the Michigan Department of State Highways and Transportation.

An atmosphere of uncertainty dominated the autumn of 1973 while Congress composed the final form of the Regional Rail Reorganization Act. The bill was signed into law January 2, 1974. The Secretary

[1]Michigan Public Service Commission, Order and Notice of Hearing, File No. RR-6992, issued December 22, 1972 and amended January 29, 1973, Lansing, Michigan.

of Transportation was given thirty days to develop a report on the railroad system of states in the Northeast and Midwest. The report, revealed on the first day of February, suggested that nearly half of the railroad route mileage of lower peninsula Michigan was "potentially excess." Communities, railroad users and state agencies with concerned clientele reacted immediately and emotionally to the thought of losing railroad service.

Interaction with state officials, railroad users and community leaders revealed a common insecurity in the lack of analytical tools with which to judge the convenience and necessity of retaining railroad service. Sound policy requires systematic treatment of facts involved in an issue. The issue confronted by communities, railroad users and state agencies presents itself in two time frames. How is each group to respond to forthcoming federal proposals for railroad line removal? In the longer run, how is each group to respond to subsequent, individual line abandonment cases? The problem in both periods can be treated similarly. The new railroad law provides jurisdiction and partial funding to subsidize continued operation of unprofitable lines or loans to purchase lines considered to be excess. Each group must develop an approach to determine whether or not to subsidize or purchase a line. The public need for basic information and criteria with which to make these judgments provides the motive for this research.

Historical perspectives of the railroad capital shortage problem and of legal precedents establishing rules for distribution of property rights associated with railroad assets are reported in Chapter II. Chapter III is devoted to analyzing the supply side of market provision of railroad service. From criteria established with a long run production-investment model, a measure of subsidy necessary to encourage operating companies to retain currently unprofitable lines is determined. The limits of alternative railroad pricing policies and of private collective action are also considered. Elements of market demand are discussed in Chapter IV. Demand functions, including service quality influences, and modal split relationships are measured for various commodity groups. Chapter V is devoted to considerations of demand for railroad service which are not communicated through the market price mechanism. Concepts developed in Chapters III-V are applied to a two county region of Michigan, in Chapter VI, with the purpose of exemplifying evaluative procedures. The breadth of this undertaking has forced the author to set aside numerous topics for research which exposed themselves during the course of this endeavor. Some of these researchable questions are summarized together with conclusions and policy implications of this work, in the final chapter.

CHAPTER II

THE EVOLVING ECONOMIC AND INSTITUTIONAL ENVIRONMENT OF RAILROADING

Railroading has had a colorful history of high finance and tough legal battles. Over the near century and a half of American railroading, the life cycle of an industry has been displayed. From the early days of excited youth, through the growing pains of adolescence, to maturity, and now to a degree of senescence, the economic and institutional environments surrounding the railroad industry have evolved along the way. Put in perspective with earlier times, contemporary railroad problems appear to be the same as they have been for years, except in degree. This chapter is included to develop this perspective by observing the recent past. Special attention is given to the perennial railroad capital shortage problem and the set of property rights which have been developed to distribute control over railroad resources and the implications of use. The Regional Rail Reorganization Act of 1973 will be reviewed briefly to note implied changes in property rights and means to finance lightly traveled rail lines.

The Railroad Capital Shortage Problem

The capital shortage problem is not new to the railroad industry. As a maturing, capital intensive industry strictly constrained by market competition and regulatory policy, railroads have found increasing difficulty obtaining attention of the capital market. A short history of railroad capital problems adds perspective to current shortages. Net real capital formation reached its peak in 1911 while the real value of road and equipment grew at a decreasing rate until the Great Depression. Ulmer demonstrated that net capital formation in railroading has occurred in long cycles which reflect, but are not overshadowed by, general business cycles.[1] From the all-time peak of 1911 until 1950, these long cycles grew in length, up to twenty years by the end of his study, and amplitudes reflected a tendency toward increasing contractions and decreasing expansions. Thus, a secular decline in net railroad capital formation has occurred since before World War I.

A sharp decline in capital formation reached a trough during World War I with rapid recovery after passage of the Transportation Act of 1920, encouraging development of a peacetime railway system. The years of depression devastated the capital positions of the entire industry. "During the depression of the 1930's about one-third of all railroad mileage was in the control of receivers or trustees."[2] Potential investment from greatly expanded traffic during the second World War was stymied by material shortages.

The end of depression and inflated wartime traffic volumes triggered a false sense of optimism for the decade of the fifties. Forecasts of continued high revenues brought recommendations for major investment programs in railroad fixed plant. Emory Johnson estimated that though

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[1]Melville J. Ulmer, Trends and Cycles in Capital Formation by United States Railroads, 1870-1950, Occasional Paper 43 (New York: National Bureau of Economic Research, Inc., 1954), pp. 25-36.

[2]John L. Weller, "Access to Capital Markets," in The Future of American Transportation, ed. by The American Assembly (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1971), p. 85.

motor carriers had caused railway travel to shrink to one-third of its one-time volume, "the tide has turned and the trend of travel by rail is again upon an upward curve."[3] With more guard James Lyne foresaw that "the nation's reliance on railway transportation is considerably less percentagewise in peacetime than in war, but is still large, with indications that its decline may have been arrested."[4]

Post-war optimism was shared neither by railroad management nor by investors. With the experience of the thirties clearly in mind and great uncertainty clouding the future, railroad management used wartime caches to pay off debts rather than invest in capital improvements. Simultaneously prices of railroad securities were extremely low reflecting the reluctance of investors to supply capital to the industry. Viewing the fifties in hindsight, Nelson describes the unfulfilled optimism for the decade.

> The economic position of the railroads has deteriorated seriously since the end of World War II. In 1945 the roads appeared to have excellent prospects. . . . But notwithstanding the factors favorable to railway progress, the past decade has been a period of stagnation rather than growth. Once again, the railroads have the symptoms of a "sick" industry, and, with few exceptions, there is no assurance that their health will improve substantially in the near future.[5]

The troubling feature of the stagnation of the fifties was the

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[3]Emory R. Johnson, The Railroads and Public Welfare: Their Problems and Policies (New York: Simmons-Boardman Publishing Corporation, 1944), p. 1.

[4]James Garnett Lyne, The Need of the Railways for Additional Fixed-Plant Capital and Possible Means of its Attainment (New York: Simmons-Boardman Publishing Corporation, 1948), p. 3.

[5]James C. Nelson, Railroad Transportation and Public Policy (Washington, D.C.: The Brookings Institution, 1959), p. 3.

accompanying general state of economic prosperity, unlike the conditions surrounding railroad stagnation of the thirties.

Low rates of capital investment continued through the anti-merger years of the early sixties. In the latter half of the decade capital expenditures by railroads rose considerably, 60.5 percent above the 1960-1964 level.[6] However, nearly three-quarters of all railroad capital expenditures in this period were allocated to equipment with the remainder applied to roadway and structures. Equipment purchases have continued strongly into the 1970's with massive but less than commensurate retirements. Table 1 shows the pattern of growth in standing freight car capacity resulting from emphasis on equipment purchases. Short experience of the 1970's reveals a greater proportion of capital expenditures going to roadway and structures but no more in absolute dollar terms than in the latter half of the 1960's, as seen in Table 2. The year 1966 may represent the peak ending the long period investment cycle beginning with Ulmer's last reported peak of 1946.

Ulmer's study of capital sources for railroad investments reveals the market in which railroading must appear attractive.[7] Prior to 1907 internal corporate financing of investments was negligible. Sales of stocks and bonds composed 90 percent of all capital acquisitions. Adoption of depreciation accounting and finance with retained earnings led railroads to finance about 40 percent of capital requirements with internal resources, during the long cycle of 1907-1916. The trend toward internal financing intensified. During the thirties much of internal

[6]Weller, "Access to Capital Markets," p. 86.

[7]Ulmer, Capital Formation, pp. 46-49.

Table 1. Standing Freight Car Capacity* for the United States: 1960-1973

Year	Cars (Number)	Average Capacity (tons/car)	Standing Capacity (thousand tons)
1960	1,965,486	55.4	108,888
1961	1,905,268	55.7	106,123
1962	1,850,688	56.3	104,194
1963	1,814,193	56.8	103,046
1964	1,796,264	58.3	104,722
1965	1,800,662	59.7	107,500
1966	1,826,499	61.4	112,147
1967	1,822,381	63.4	115,539
1968	1,800,375	64.3	115,764
1969	1,791,736	65.8	117,896
1970	1,784,181	67.1	119,719
1971	1,762,135	68.4	120,530
1972	1,716,937	69.6	119,499
1973 (est.)	1,710,659	70.5	120,601

Source: Yearbook of Railroad Facts, 1974, Association of American Railroads, pp. 51, 53.

*Standing freight car capacity is the product of average car capacity and number of cars. True capacity is dependent upon the rate of turnover in use.

Table 2. Expenditures for Capital Improvements by U.S. Railroads: 1960-1973

Year	Total	Equipment	Roadway & Structures	Roadway & Structures
	(thousands of dollars)			(Percent)
1960	919,154	633,490	285,664	31.08
1961	646,425	427,130	219,295	33.92
1962	832,938	593,369	239,569	28.76
1963	1,043,788	784,874	258,914	24.81
1964	1,417,263	1,139,683	277,580	19.59
1965	1,630,687	1,303,602	327,084	20.06
1966	1,952,805	1,554,223	398,581	20.41
1967	1,522,478	1,148,381	374,097	24.57
1968	1,186,979	818,720	368,259	31.02
1969	1,509,394	1,088,712	420,681	27.87
1970	1,351,439	993,095	358,344	26.52
1971	1,177,627	863,517	314,110	26.67
1972	1,215,581	847,623	367,958	30.27
1973 (est.)	1,342,138	892,690	449,448	33.49

Source: <u>Yearbook of Railroad Facts, 1974</u>, American Association of Railroads, p. 57.

financing occurred with defaults on bonds and interest on debt. Internal financing reached a peak during the forties when nearly all capital requirements were serviced internally. As noted earlier, wartime earnings were even used to retrieve stocks and bonds outstanding. Since World War II total internal financing has not been possible due to high operating ratios.[8] Table 3 shows recent operating ratios for Michigan and system operations for railroads found in the state of Michigan. Though Northeastern railroads have been forced to incur external debt, a recent Department of Transportation reply to a questionnaire from Congress revealed that recent railroad bankruptcies have not been caused so much by unmanageable debt structure as by insufficient earnings from operations. Revenues have simply been so small relative to operating expenses as to leave insufficient cash to cover fixed charges.

Various reasons have been developed to explain the railroads' inability to attract capital and generate revenues. Attraction of capital is inhibited by the uncertain financial outlook for railroads as a result of a mixture of several conditions. Revenues sufficient to cover fixed charges tend to be consumed in noncapital expenditures or inhibited by inability to compete under current economic and policy conditions. Causes of railroad decline include inflexible rate regulation, inefficient labor work rules, rising material and fuel costs, differential property taxation, public subsidization of competing modes, comparatively disadvantageous economic structural shifts, and unresponsive abandonment procedures.

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[8]Operating ratio denotes railroad operating expenses as a proportion of operating revenues. Smaller ratios imply more funds left to cover capital charges after variable expenses.

TABLE 3. System and State Operating Ratios* for Michigan Line-Haul Railroads: 1968-1972

	Ann Arbor		Boyne City**		Chesapeake & Ohio		Chicago & Northwestern	
	System	State	System	State	System	State	System	State
1968	85.46	94.35	48.23	48.23	79.4	76.5	85.43	86.03
1969	92.68	101.96	55.99	55.99	80.9	78.2	87.97	98.65
1970	85.05	93.52	151.29	151.29	78.8	76.1	81.29	101.17
1971	91.98	93.64	188.68	188.68	80.7	78.5	80.50	104.06
1972	93.07	---	105.79	105.79	76.2	74.2	79.47	---

	Milwaukee Road		Detroit & Mackinac**		Detroit & Toledo S.L.		Detroit, Toledo & Ironton	
1968	81.71	66.97	82.85	82.85	70.45	70.45	71.69	50.58
1969	85.70	61.61	88.89	88.89	73.26	73.26	73.09	55.61
1970	85.84	111.00	87.67	87.67	73.28	73.28	77.44	62.84
1971	82.20	81.99	86.03	86.03	70.42	70.42	74.35	60.19
1972	84.84	---	82.79	82.79	69.88	69.88	73.94	---

	Escanaba & Lake Superior**		Grand Trunk Western		Lake Superior & Ishpeming**		Norfolk & Western	
1968	77.02	77.02	82.5	82.2	78.98	78.98	69.74	106.17
1969	93.98	93.98	89.6	87.7	72.31	72.31	69.88	104.68
1970	106.56	106.56	105.1	105.0	80.68	80.68	72.02	106.30
1971	110.82	110.82	90.3	90.2	91.85	91.85	72.51	90.46
1972	113.44	113.44	89.2	88.1	99.45	99.45	71.17	87.45

	Penn Central		Port Huron & Detroit**		Soo Line	
1968	83.62	---	62.45	62.45	75.38	63.35
1969	85.60	---	57.58	57.58	75.57	63.74
1970	92.08	---	73.02	73.02	73.76	70.56
1971	88.01	---	69.97	69.97	74.11	70.11
1972	84.09	---	---	---	72.81	67.54

Source: Marc A. Johnson, Summary: Michigan Public Service Commission Railroad Hearings, July, 1973.

* The ratio of operating cost to operating revenue is shown in percentage terms.

** Railroads wholly contained within the state.

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Rate regulation is criticized by railroads and many economists as responding to market changes too conservatively and too late. Inability of rates to move quickly with market conditions tends to discourage traffic in overpriced markets and stifle revenue generation in underpriced markets. Too, accounting schemes for allocation of joint and common costs often distort railroad service prices from those which would give either the railroads a higher revenue or the public a level of service for which they are willing and able to pay. Rates tend to be raised in an "across the board" fashion which does not necessarily reflect market conditions.

Labor work rules established by labor-management negotiation are said to require inefficient overuse of railroad employees in individual operating tasks. Most notable has been the featherbedding dispute over whether train firemen are to be retained. Unnecessary workers, management maintains, is a major cost item at rapidly rising wages. These payments in wages reduce revenues applicable to fixed charges.

Another drain on revenues is rapidly rising prices of fuel and other materials required in operating a railroad. When material and fuel prices rise relative to freight rates, net revenues are pinched, reducing earnings which may be applied to capital formation.

Methods of state ad valorem taxation have been criticized for more than a decade for unfairly valuing railroad properties above the values of adjacent lands or assessing higher rates than those charged to local property. The debate grew hot between railroads and local governments during the 1960's and many state governments moved to equalize tax treatment. Michigan has been above the dispute since collection of railroad ad valorem taxes is a state function.

By a process of elimination, Lyne concluded that the single most important cause of the railroads' poor post-war capital position was the implicit public differential subsidization of competing transport modes.[9] Public investments in highways, waterways and airways and airports without charges on traffic proportional to cost tend to allow pricing of users' services below cost, giving user modes an advantage in transport markets, leading to overinvestment in competing modes and underinvestment in railroads. Uncertainty associated with public investment policies tends to dampen the railroad outlook.

> There is hardly a major railroad in the country which does not face the probability of being paralleled by a toll-free highway of the "super" category, which should greatly decrease costs of truck operation and increase speed, without any commensurate addition to the charges on the specific traffic which immediately benefits from the facility.[10]

Similar conclusions are reported for waterway, airway and airport developments. Emory Johnson also views implicit public differential subsidization of modes as the chief problem behind the railroads' loss of traffic.[11] His argument is based not on "fair treatment" of modes but upon the pricing distortion which affects "the development and maintenance of a well-balanced, efficient and economical national transportation system."

Major structural shifts in the economy have also been used to explain sluggish growth of railroad demand. Emory Johnson was early in explaining that economic structural shifts may create a shift in

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[9]Lyne, Fixed-Plant Capital, p. 149.

[10]Ibid., p. 153.

[11]Emory Johnson, Railroads and Public Welfare, pp. 14-15.

comparative advantage of transportation away from railroads.[12] Economic moves Johnson cited are shifts of energy production to raw material sites with more extensive transmission line webs for power distribution and shift to electric and fuel oil power sources allowing wide-scale decentralization of industry with emphasis on marketing and distribution functions which favor motor carriage.

The Task Force on Railroad Productivity of the National Commission on Productivity attributes the railroad problem to several characteristics of the dynamic transport market: 1) general slow growth of intercity freight traffic, 2) altered composition of freight traffic, 3) changing spatial pattern of commodity flows, 4) development of new modes strengthening intermodal competition, and 5) lagging management and regulatory progress falling behind the pace of a changing market environment.[13] As economies mature freight volumes in general and freight suited for railroads tends to grow less rapidly than the output of the general economy. This is demonstrated by comparing post-war rates of growth in intercity traffic and gross national product. In the period 1947-1972 total intercity freight ton-miles, excluding oil pipelines, grew 2.2 percent annually compared with annual gross national product growth of 3.8 percent.[14]

Evolution of the economic structure has also brought changes in the patterns of composition and distribution of traffic. Bulk commodities,

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[12] Ibid., p. 33.

[13] Task Force on Railroad Productivity, Improving Railroad Productivity, Report to the National Commission on Productivity and the Council of Economic Advisors, November, 1973 (Washington, D.C.: National Commission on Productivity, 1973), pp. 1-50.

[14] Ibid., p. 3.

for which railroads hold an advantage, tend to be highly income inelastic. Increased consumer incomes tend to create demands for labor and capital intense products and services rather than products of high raw material requirements. Technological developments of raw material substitutes and material economy have tended to replace low-value, bulk material movements such as coal and glass with higher valued petroleum and plastic which favor motor carriage. A higher proportion of traffic is generated in manufactured products which require higher service standards than bulk materials.

Bulk commodity hauls are increasing in length and density which favor railroad traffic retention, but replacements of raw building materials with synthetics and petroleum for coal tends to favor other modes. The trend toward decentralization of manufacturing industries toward market oriented operations slows growth in traffic in manufactures and deconcentrates deliveries, making trucking more competitive both in volume and cost. While product differentiation has dampened decentralization of production, again size of shipments are reduced detracting from railroad advantage. The long-term evolution to suburbanized residential patterns and subsequent dispersion of wholesale and retail sales has made the flexibility of motor carriage very attractive for movements of final manufactured goods.

The consequence of changing composition and distribution patterns has been a declining share of railroad participation in total intercity freight movements. The railroad share of total intercity freight ton-miles has steadily declined from 65.3 percent in 1947 to 38.7 per cent in 1971. The share for motor carriage has remained stable near 21.5 percent since 1958, but has been increasing relative to the share of freight movement by railroads. Total tons originated by railroads during the 1970's have not changed appreciably since 1966 nor do tonnages differ greatly from traffic originated during the post-war forties.[15] Modes growing fastest are air, pipeline, and river carriage. Air transport remains relatively insignificant carrying less than one-fourth of one percent of total intercity freight ton-miles during 1970 and 1971, though receiving a much higher relative share of total traffic revenues. Pipelines and inland water carriage compete with railroads for bulk commodities while trucks compete most strongly for manufactured goods. The railroads are caught in the middle of major new developments in other modes of transport.

Finally, policy toward rail line abandonments has been cited as a major cause of railroad capital problems. The argument is that slow, expensive abandonment procedures inhibit adjustment by railroads to changing economic and social circumstances. This argument was one of the most strongly and consistently expressed by line haul railroad carriers in 1973 hearings before the Michigan Public Service Commission.[16] Weller suggests that the problem of overcapacity in fixed rail plant is one root cause of railroad inability to adjust to a changing environment.

> . . . the breakdown of the railroads leading to their takeover by the federal government in World War I seems to have resulted from overbuilding of the system and from refusal of

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[15]Association of American Railroads, Yearbook of Railroad Facts: 1974 Edition (Washington, D.C.: Association of American Railroads, 1974), p. 28.

[16]Marc A. Johnson, Summary: Michigan Public Service Commission Hearings, Report to the Michigan Public Service Commission, Lansing, Michigan, July, 1973 (East Lansing: Department of Agricultural Economics, 1973), pp. 52-53.

> the Interstate Commerce Commission to permit rate increases between 1910 and 1915, a period when railroad wages and other costs were rising rapidly. The problem of rail capital inflow began at that time, before the roads had been exposed to significant competition from other modes.[17]

An early study of railroad abandonments by Cherington provides support for this view. In the first attempt by any railroad to reorganize with a massive abandonment plan, the ICC initially refused more than half of the Boston and Maine's applications. The commission said

> The evidence seems to be conclusive that not a few of the lines which it is now proposed to abandon should never have been built. At the time of their projection as independent enterprises it seems to have been understood that some of them were built for purely competitive or strategic reasons. . . . But irrespective of the origin of an existing line, people gather about it and create for themselves an interest in and a dependence upon it.[18]

Meyer terms these effects of reduced property values "transition capital cost problems" which he diminishes in cases where substitute modes or modified transport technology can handle abandoned railroad traffic, even at some higher cost.[19] The Boston and Maine applications, refused in 1925, were granted expeditiously with the advent of the Great Depression.

The actual cause or mix of causes of railroad capital problems appears in a state of uncertainty. Conclusions on the cause of the railroad capital problem have been drawn from educated conjecture. The battle of quotations from prominent and experienced professionals does

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[17]Weller, "Access to Capital Markets," p. 92.

[18]Charles Cherington, "II. Railroad Abandonment in New England, 1921-37," Journal of Land and Public Utility Economics, 14 (May, 1938), 191-200.

[19]John R. Meyer, et al., The Economics of Competition in the Transportation Industries (Cambridge: Harvard University Press, 1960), pp. 256-257.

not suffice. While identification of the actual cause of railroad capital problems is not the subject of this research, theoretical and empirical developments are designed which will describe the implications of both railroad abandonment policy and traffic shifts on railroad capital requirements.

A Half Century of Line Abandonments

Shifting markets and financial woes have encouraged railroad firms to seek removal of lightly traveled roadway. Programmed abandonment policy for major firm readjustments has been thwarted by the regulatory process. The result has been resignation to the piecemeal approach of numerous applications to abandon small segments of trackage. Table 4 reveals the magnitude and disposition of abandonment behavior since the Interstate Commerce Commission was charged with responsibility to oversee line extensions and contractions. Table 5 is included to demonstrate the downward trend in new line extensions, reinforcing the total decline in national roadway mileage.

Throughout the decade of the twenties, new roadway extensions more than offset line closures. This condition was reversed during the Depression of the thirties and the absolute decline in rail lineage has continued since. In the fifty-three year period of ICC roadway supervision, permission has been granted to abandon five times as many miles of roadway as has been granted to new extensions.

An average of eighty-eight applications to abandon roadway have been granted each year of the period 1921-1973, affecting an average of 1,294 miles annually. Number of applications approved and mileage affected move together. During the decade of the twenties, the last

TABLE 4. Applications for Certificates of Public Convenience and Necessity to Abandon Railroad Lines in the United States, 1921-1973.*

Year	Applications		Granted		Denied		Cumulative Granted	
	Number	Miles	Number	Miles	Number	Miles	Number	Miles
1921	49	910.00	40	701.94	1	28.00	40	701.94
1922	47	808.46	30	526.53	5	78.82	70	1,228.47
1923	36	964.94	19	523.41	1	1.5	89	1,751.88
1924	52	949.82	30	453.84	3	69.13	119	2,205.72
1925	57	883.21	46	651.98	1	14.66	123	2,857.70
1926	46	937.19	49	592.56	5	73.30	172	3,450.26
1927	56	792.26	52	830.61	6	106.92	224	4,280.87
1928	53	752.21	61	587.05	2	59.72	285	4,867.92
1929	69	834.92	48	539.54	1	16.72	333	5,407.46
1930	75	980.83	72	1,807.46	5	226.24	405	7,214.92
1931	88	1,075.53	89	1,019.31	3	42.07	494	8,234.23
1932	114	2,281.43	90	1,418.27	1	40.60	584	9,652.50
1933	153	3,263.22	129	2,404.26	2	33.97	713	12,056.76
1934	125	2,013.49	154	2,514.22	6	161.55	867	14,570.98
1935	122	2,537.17	100	1,691.82	6	310.43	967	16,262.80
1936	125	1,896.89	116	1,903.00	5	111.86	1,083	18,165.80
1937	134	2,179.28	116	1,547.37	5	93.80	1,199	19,713.17
1938	127	2,470.62	123	2,014.06	6	63.03	1,322	21,727.23
1939	121	2,561.78	106	2,137.80	5	60.51	1,428	23,865.03
1940	115	1,781.44	124	1,919.40	5	84.27	1,552	25,784.43
1941	139	2,317.58	111	1,938.24	2	109.35	1,663	27,722.67
1942	227	3,534.93	184	2,407.14	15	308.46	1,847	30,129.81
1943	116	1,508.72	146	1,782.77	19	349.14	1,993	31,912.58
1944	72	1,173.18	61	801.33	13	343.76	2,054	32,713.91
1945	45	674.40	55	801.98	4	123.61	2,109	33,515.89
1946	60	1,747.24	37	669.79	6	273.09	2,146	34,185.68
1947	85	1,073.50	63	1,241.11	1	2.00	2,209	35,426.79
1948	65	781.31	57	907.36	6	49.30	2,266	36,334.15
1949	80	1,177.80	51	873.31	3	28.72	2,317	37,207.46
1950	71	886.29	80	954.62	8	109.50	2,397	38,162.08
1951	69	815.12	58	566.44	5	181.09	2,455	38,728.52
1952	91	1,294.13	84	1,305.75	4	98.59	2,539	40,034.27
1953	72	976.01	77	1,101.68	1	6.22	2,616	41,135.95
1954	61	497.63	69	999.74	3	14.42	2,685	42,135.69
1955	80	975.82	62	428.73	0	-	2,747	42,564.42
1956	58	731.35	69	822.71	1	44.82	2,816	43,387.13
1957	74	1,190.45	65	588.51	2	88.82	2,881	43,975.64
1958	96	2,061.84	85	1,825.36	2	50.50	2,966	45,801.00
1959	86	1,203.20	94	1,179.73	4	136.72	3,060	46,980.73
1960	100	1,681.56	69	771.82	9	120.20	3,129	47,752.55
1961	98	1,140.54	101	1,167.16	6	376.32	3,230	48,919.71
1962	122	1,869.13	95	1,582.28	2	53.15	3,325	50,501.99
1963	127	1,937.40	110	1,688.40	3	72.65	3,435	52,190.39
1964	109	1,528.18	83	811.32	4	74.12	3,518	53,001.71
1965	107	2,224.0	117	1,538.5	1	121.3	3,635	54,540.21
1966	106	1,920.1	92	1,054.4	5	334.0	3,727	55,594.61
1967	72	860.0	85	817.3	7	95.5	3,812	56,411.91
1968	76	2,036.3	74	1,890.4	4	76.1	3,886	58,302.31
1969	136	2,286.6	89	1,319.8	1	12.2	3,975	59,622.11
1970	104	1,762.0	82	1,782.0	2	64.9	4,057	61,404.11
1971	241	3,142.3	129	1,286.6	3	39.5	4,186	62,690.71
1972	273	3,978.4	268	3,457.7	3	47.9	4,454	66,148.41
1973	266	4,436.3	198	2,428.3	5	153.5	4,652	68,576.71

*Each annual entry was obtained from the corresponding Annual Report of the Interstate Commerce Commission.

TABLE 5. Applications for Certificates of Public Convenience and Necessity for New Line Extensions in the United States, 1921-1973.*

	Applications		Granted		Denied		Cumulative Granted	
Year	Number	Miles	Number	Miles	Number	Miles	Number	Miles
1921	67		39	404.70			39	404.70
1922	53	2,941.28	27	446.33	6	259.35	66	851.03
1923	50	2,914.51	28	881.59	2	15.75	94	1,732.62
1924	42	2,564.66	26	1,318.35	7	2,298.60	120	3,050.97
1925	73	3,512.50	46	908.84	3	234.03	166	3,959.81
1926	51	1,280.52	52	1,573.70	10	503.12	218	5,533.51
1927	41	1,257.73	39	1,027.27	10	593.86	257	6,560.78
1928	46	1,380.79	33	717.19	5	222.19	290	7,277.97
1929	79	3,307.26	45	618.20	8	464.48	335	7,896.17
1930	37	737.83	54	1,596.01	5	247.50	389	9,492.18
1931	21	319.40	29	244.05	6	106.73	418	9,736.23
1932	9	850.86	11	38.03	10	952.87	429	9,774.26
1933	12	491.29	8	32.30	5	23.77	437	9,806.56
1934	8	174.453	19	70.54	4	881.73	456	9,877.10
1935	11	196.91	13	88.67	2	128.00	469	9,965.77
1936	7	106.96	6	105.08	1	236.20	475	10,070.85
1937	17	97.28	8	38.20	0	-	483	10,109.05
1938	5	237.23	11	36.659	1	210.00	494	10,145.71
1939	8	45.54	4	29.77	2	10.08	498	10,175.48
1940	13	37.31	9	27.41	0	-	507	10,202.89
1941	14	50.34	17	44.84	1	9.51	524	10,247.73
1942	6	24.86	6	37.61	1	1.95	530	10,285.34
1943	8	43.98	6	39.17	1	.08	536	10,324.51
1944	25	152.78	16	73.26	2	4.40	552	10,397.77
1945	16	101.22	14	138.04	2	12.90	566	10,535.81
1946	20	159.45	10	47.36	2	3.25	576	10,583.17
1947	20	335.35	16	133.37	2	14.00	592	10,716.54
1948	22	126.39	18	116.78	1	229.00	610	10,833.32
1949	12	104.57	9	80.95	1	4.00	619	10,914.27
1950	12	83.50	13	43.04	1	4.50	632	10,957.31
1951	21	154.18	15	92.26	1	7.00	647	11,049.57
1952	13	72.58	8	32.55	2	17.40	655	11,082.12
1953	22	161.04	13	64.52	3	10.49	668	11,146.64
1954	11	49.56	9	86.88	1	1.51	677	11,233.52
1955	17	95.98	10	48.27	1	5.50	687	11,281.79
1956	14	75.69	14	89.30	4	13.04	701	11,371.09
1957	8	42.52	10	54.44	3	13.54	711	11,425.53
1958	10	88.44	10	77.92	1	.79	721	11,503.45
1959	13	135.90	9	62.31	1	9.07	730	11,565.76
1960	14	44.11	10	68.06	1	.90	740	11,633.82
1961	22	99.18	20	60.29	3	18.67	760	11,694.11
1962	9	14.09	12	26.34	2	36.03	772	11,720.45
1963	20	164.13	10	15.49	1	.95	782	11,735.94
1964								
1965	20	202.6	18	275.8	5	56.5	800	12,011.74
1966	20	166.0	15	127.4	1	14.8	815	12,139.14
1967	15	142.1	20	201.6	0	-	835	12,340.74
1968	12	142.1	9	121.3	2	51.4	844	12,462.04
1969	13	79.4	17	98.7	1	26.7	861	12,560.74
1970	11	70.2	5	37.0	0	-	866	12,597.74
1971	13	669.5	12	616.9	0	-	878	13,214.64
1972	10	41.9	10	22.7	0	-	888	13,237.34
1973	11	261.6	5	84.7	2	5.1	893	13,322.04

*Each annual entry was obtained from the corresponding Annual Report of the Interstate Commerce Commission.

period of significant roadway building, number of abandonment applications granted oscillated near half the fifty-three year average. The Depression brought a sharp rise in requests and approval of abandonments as one means to save a beleaguered industry. Interest remained high until the United States became involved in the second World War. Throughout the war period and the post-war forties and fifties, number of abandonment applications granted remained below the fifty-three year average. During the merger movement of the sixties, the annual number of abandonment certificates granted rose to the average level for the entire period. The late sixties brought the culmination of several large mergers and a succession of railroad bankruptcies ensued. These forces have led to the highest level of abandonment activity in the nation's history.

New line extensions have taken the opposite pattern. During the period 1921-1973, an average of seventeen cases were approved annually for an average of 256 miles per year. During the decade of the 1920's, yearly number of certificates granted was far above the fifty-three year average; extensions exceeded abandonments. Since the beginning of the Depression, interest in extending roadway plants has remained below the fifty-three year average, with few exceptions.

The State of Michigan has experienced some of the most intense abandonment activity in the nation. Of the forty-eight contiguous states, Michigan ranked second in number of roadway miles affected by certificates to abandon, between 1921 and 1945; only Texas had more mileage affected.[20] During the same period, the state ranked fourth in percent

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[20]Charles R. Cherington, The Regulation of Railroad Abandonments (Cambridge: Harvard University Press, 1948), pp. 105-106.

of total state mileage with certificates to abandon roadway, following New Hampshire, Nevada and New Mexico.[21]

The recent national trend of accelerated abandonment action has also affected the state with strong intensity. Of the 6,614 mile railroad plant present in Michigan in 1965, abandonments and lack of extensions reduced roadway by six percent by the beginning of 1973.[22] Another nine percent of the state's current 6,223 miles of roadway was under formal application for abandonment when a District Court of Pennsylvania ordered applications held in abeyance, pending report of a related environmental impact study. More than half of these lines involve the package of Penn Central proposals to abandon large sections of roadway.

Property Rights and Railroading Resources

Railroad abandonment is not a new phenomenon, but the significance of railroad line closures to the economy and the public interest has changed continually for more than a century. Railroad regulation has defined two concepts of the "public interest." The national public interest has been interpreted as preservation of a complete and efficient national transportation system. The local public interest has been identified as protection of individual and community properties and opportunities. Legal protection of these public interests has evolved as local, state and federal agencies have considered effects associated with abandonment actions. The product of this evolution is a set of

[21]Percentages are based in year 1943 to take account of new line extensions.

[22]This calculation was derived from information in the files of the Michigan Public Service Commission.

basic legal principles and practices governing public control of railroad line closures. A brief historical sketch of regulatory principles and practices will reveal the institutional environment shaping actions. This review, drawing completely upon the work of others, focuses upon the few basic principles which have governed the distribution of rights associated with railroading resources.

Public influence over line closures was evidenced as early as the 1860's. Though federal jurisdiction was not established until passage of the Transportation Act of 1920, states acted early to influence rail roadway dispositions.[23] Earliest public control operated through state courts in response to individual plaintiff protests. State courts developed the principle that companies established to serve the public interest held no obligation to continue this service unless such companies were granted special rights and privileges by the people. Since railroads received special privileges in terms of powers of eminent domain, land grants and local financial assistance, state courts found railroad companies obliged to the people of respective states to continue services initiated under privilege. Locklin provides one example in the spirit of the following quotation from a Kansas Supreme Court ruling of 1894.

> The railway corporation takes its franchises subject to the burden of a duty to the public to carry out the purposes of the charter. The road, when constructed, becomes a public instrumentality, and the roadbed, superstructure, and other

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[23]Charles R. Cherington, Railroad Abandonments, pp. 17-25.

> permanent property of the corporation are devoted to the public use. From this use neither the corporation itself, nor any person, company, or corporation deriving its title by purchase . . . can divert it without the assent of the state.[24]

A single exception to this principle applied to operating companies faced with incipient financial failure. The state was prohibited from forcing maintenance of service on lines when such continuance threatened financial solvency of an entire system. Enforced continuation of service by public command resulting in insolvency, constitutes confiscation of private property without due process of law. This principle was upheld by the United States Supreme Court in the case of Brooks-Scanlon Co. v. Railroad Commission of Louisiana, in 1920. This limiting principle, known as the Brooks-Scanlon doctrine, has become the benchmark of abandonment justice.

Abandonment administration shifted to newly created state utility regulatory commissions at the turn of the century. Guiding principles were not changed radically from those established by state courts. Protection of railroad stock and bond holders and protection of the public interest associated with a strongly viable transportation system, were given precedence over the convenience of local railroad users in cases where railroad solvency was threatened. However, the convenience of local interests, guaranteed in trade for charters of incorporation, were protected when continued service did not threaten the viability of railroads, essential to the broader public interest.

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[24]Naylor v. Dodge City, Montezuma & Trinidad R.R. Co., 36 Pac. 747, 748 (1894), in Philip D. Locklin, <u>Economics of Transportation</u> (Homewood, Ill.: Richard D. Irwin, Inc., 1966), p. 575.

Federal control of railroad abandonment was established with the Transportation Act of 1920. The Act represented sweeping changes in the Interstate Commerce Act of 1887 designed to facilitate the transfer of railroad management back to private companies following government operation during World War I. Railroad abandonment was a non-issue.[25] Abandonment cases were infrequent and the future of railroad expansion was viewed with optimism.

Only one significant debate involved appropriate division of authority between federal and state agencies in regulating new line extensions and abandonments. Abandonments and new line extensions were not treated separately and new line extensions appeared a topic of future importance. States' rights advocates feared federal commissioners would neither understand nor give "proper" protection to local interests. Federalists noted the importance of protecting the broader national public interest. The House version of the bill included an amendment to permit federal jurisdiction only for line alterations spanning more than a single state. Such cases were rare. The Senate version provided federal authority over all route adjustments. The Senate version was adopted in Conference Committee and became law. Federal regulatory jurisdiction was outlined briefly without detail.

> . . . No carrier by railroad subject to this chapter shall abandon all or any portion of a line of railroad, or the operation thereof, unless and until there shall first have been obtained from the commission a certificate that the present or future public convenience and necessity permit of such abandonment.[26]

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[25]Cherington, Railroad Abandonments, pp. 25-40.

[26]U.S. Code, Title 49, Part I, Sec. I, par. 18 (in part).

Jurisdictional authority of the ICC to regulate rail abandonments was tested immediately in the courts. The United States Supreme Court in Colorado v. United States, et al., 271 U.S. 153 (1926), based its arguments on the supremacy of the broader public interest.

> The exercise of federal power in authorizing abandonment is not an invasion of a field reserved to the state. The obligation assumed by the corporation under its charter of providing intrastate service on every part of its line within the state is subordinate to performance by it of its federal duty, also assumed, efficiently to render transportation services in interstate commerce.[27]

With this support of the Supreme Court and the complexion of the Act, the ICC had the opportunity to develop a strategy of abandonment in broad national terms. However, precedent established in state actions prior to 1920 and continual pressure from state officials prevented this strategy from developing. The ICC developed a particularist approach to the "public interest" focusing upon local implications of railroad abandonment for local communities. The broader national interest was protected by continued application of the Brooks-Scanlon doctrine as a minimum principle and liberalization of provisions for branch line abandonments by solvent companies. The ICC warned in the Proposed Abandonment of Branch Line by Colorado and Southern Railway Co., 72 ICC 315 (1922), that

> It is not in the public interest that even a strong line like the applicant should permanently operate parts of its system that do not yield revenues sufficient to pay operating expenses.[28]

In the later case of Long Island Railroad Company Abandonment, 166 ICC 671 (1930), the ICC maintained discretion over line abandonments for

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[27]Cherington, Railroad Abandonments, p. 52.

[28]Ibid., p. 50.

companies of all degrees of profitability.

> Any unnecessary burden upon the transportation system of the country is an unreasonable burden. While it is true that loss from operation from a portion of a railroad system will not in every case justify the abandonment of such operation, it is also true that circumstances may justify the abandonment of an unprofitable line notwithstanding the prosperity of the system as a whole. The circumstances of each case must govern its disposition.[29]

The particularist approach was supplemented by a principle of "balancing of interests" to resolve conflicts.[30] This principle seeks to balance the probable losses to the railroad through continued operation against probable losses suffered by the local public through abandonment. Railroads must prove that the line under application has been and is likely to continue to be a deficit operation. Local protestants must prove their ability and willingness to provide enough traffic to clear the deficit in the near future.

Early concern for local rail users was evidenced in the ICC's denial of requests to abandon segments of the Boston and Maine Railroad. In 1925, the Boston and Maine Railroad proposed the first package abandonment reorganization policy in history, known as the Loring Plan. Of seven applications, composing the first battery of requests, four were denied. The ICC stated that

> Irrespective of the origin of an existing line, people gather about it and create for themselves an interest in and a dependence upon it. Under these circumstances abandonment brings about the kind of hardships with which it is difficult to deal. The sufferers in such cases have no redress against those guilty of the original error.[31]

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[29] Ibid., p. 56.

[30] Ibid., pp. 125-136.

[31] Cherington, "Abandonment in New England."

Strict adherence to the principle of "balancing of interests" led to the failure of the package abandonment procedure for reorganization.

Treatment of the Loring Plan induced a very cautious abandonment behavior by railroad companies. Historically abandonment applications have been granted in a large proportion of cases. Despite liberalization of the principles governing rail line abandonments, relative to those applied by state regulatory commissions, applications were tendered only after close scrutiny by railroad firms. After the ICC refused so many requests of the Loring Plan, few applications even appeared. The restrictive tone set early by the ICC limited abandonment attempts to those lines with only negligible traffic. Restrictive practices in the height of economic prosperity mark the ICC's regard for local interests when railroad companies are not threatened with insolvency.

With the advent of the Depression, the ICC yielded more abandonment decisions favorable to railroad requests. Economic conditions had changed but the principles established for disposing of abandonment cases had not changed. More cases involved incipient company failures. More application was made of the limiting, base principle of protecting property interests of owners and creditors and of protecting the strength of the railroad system in the broader public interest.

Throughout the history of abandonment regulation, disposition of cases has varied with general economic conditions, but basic principles guiding decisions appear quite consistent. The Brooks-Scanlon doctrine protects the property of railroad creditors and stockholders in cases of severe financial disaster. Beyond this minimum the ICC has sought to balance the losses of the railroad with the losses of local communities. Procedures for presenting each side of a case then become important.

The Regional Rail Reorganization Act of 1973

The capital shortage problem of railroads has been dramatized recently by the bankruptcy of the Penn Central Railroad and six other Northeastern railroad companies. The Regional Rail Reorganization Act of 1973 was designed to provide continued local railroad service to communities on lines of the bankrupt roads. This act implies no major discontinuity in basic principles of abandonment justice, but does imply a shift in emphasis of public control, which may result in significant changes in the distribution of rights and responsibilities. The departures from established procedure implied by the Act have been incorporated in more general legislation, which would apply to the entire nation.

The Regional Rail Reorganization Act of 1973 has been established to remedy an immediate problem. Two new corporations have been established to maintain essential service to customers of financially torn railroad companies. The United States Railway Association (USRA) is a nonprofit government corporation charged with the responsibilities of designing a regional railroad system plan and distributing aid and loans to states and local transportation authorities for subsidy or purchase of operations not included in the system plan. The Consolidated Rail Corporation (CRC) is a for-profit common carrier established to acquire and operate railroad properties of bankrupt companies, which are considered essential.

The final system plan will identify rail lines of companies in reorganization to be continued in service. The lines may be purchased by the CRC or by existing solvent railroads in the region. The plan will also specify those properties which are of value for public uses other than transportation, such as recreation. Lines designated as nonessential will be abandoned if railroad users, communities and states fail to purchase the line or subsidize operation.

The Brooks-Scanlon doctrine remains the limiting principle of abandonment justice. Neither railroad companies nor creditors will be forced to continue operations with financial losses. Nor will individuals be forced to relinquish property without compensation.

The shift of emphasis implied by the Act places greater weight upon the national public interest and less on local public interests, than has been practiced previously. As the Supreme Court and the ICC established early in this century, the national public interest lies in maintenance of a strong, efficient transportation system. However, implementation of an abandonment regulatory policy emphasized the balancing of local public effects and railroad financial effects of line closure. At this time of regional system crisis, the Act calls for closer attention to the broader national interest, subordinating local concerns to a secondary position.

Previously, the balancing of interests approach to adversary proceedings required both communities and the railroad to bear the burden of proof in argumentation. However, the railroad bore the financial burden. When a local public interest was determined to warrant continued service, railroads were ordered to continue such service wholly at railroad expense. Under rules established by the Act, both disputing parties continue to bear the burden of proof, but financial responsibility for continuation of potentially unprofitable operations has been shifted to the railroad user. The new rules provide a market test of local willingness and ability to pay for continued railroad service, given the existence of various transport alternatives.

During the first two years of transition states, local communities and regional transportation authorities will be eligible for federal financial and consultation assistance. Up to 70 percent of operating losses incurred by local railroad enterprises may be offset by federal rail service continuation subsidies. Where operational subsidies are not requested, federal sources may provide 70 percent loans for local purchase of lines and 70 percent loans or loan guarantees for repair or restoration of acquired properties. Consultation assistance to determine the level of subsidy required for solvency may be requested of the Rail Services Planning Office of the Interstate Commerce Commission.

The shift of financial responsibility for continued local railroad service to local agents has created requirements of investment decision rules regarding branch line operations. Local communities must be able to determine their own willingness to pay for a level of continued railroad service and whether this willingness is sufficient to attract the level of service desired. The next three chapters are devoted to determination of the boundaries of market and public provision of local railroad services.

CHAPTER III

THE MARKET BOUND -- SUPPLY

Railroad companies are highly complex producers of transportation services operating simultaneously in a market and an administered environment. Despite the influence of regulation, the market continues to offer assortments of variously valued opportunities requiring decisions regarding allocation of scarce resources. Abstraction from administered rule making will allow observation of the direction and magnitude of market forces influencing economic decision making. This amounts to viewing regulations as a set of limiting rules within which the will of management is recognized.

The objective of this and the next chapter is to develop a set of market bounds established by the behavior of direct market participants and by technical constraints, assuming no administered restraints and no responsibility for external effects of resource use. The bounds of supply in this market are shaped by technical limitations of the production function and by railroad cost structure which, in turn, is influenced by sellers and competitors in factor markets. The bounds of demand are shaped by the demand and supply of commodities to be moved and by alternative offerings of substitute and complementary transportation services. Each side of the market will be treated separately, at first, then integrated to establish the complete market bound to provision of service on particular railroad lines.

Railroad firms have long served to exemplify new twists in production theory, due to their fascinating array of unusual economic characteristics. These same characters require application of a rich set of theoretical principles as guide to a solution of the railroad line disinvestment problem. Various elements of theory will be applied to railroading, all of which serve to build appropriate investment-disinvestment decision criteria applicable in practice. Outputs, inputs and their relationship will be explicitly defined and related to cost relationships and notions of rail plant capacity. Synthesis of two complementary approaches to the interaction of production and investment will serve as the ground for development of roadway investment-disinvestment criteria. Measures will be developed for the magnitude of subsidy necessary to neutralize market forces for continuing desired operations lying beyond the market bound. Finally, a crude supply relationship for a range of product prices is considered to test the potential power of alternative pricing policies and private collective action in creating railroad revenues.

Multiple Outputs

Outputs of production are best defined in relation to the perceptions of consumers. Marketable products of transportation firms are the time and place utilities injected into people and commodities which consumers perceive as having positive value. Consumers discriminate between these utilities as they are associated with different commodities and different origin and destination locations. Haney described this notion earlier.

> [Commodities] differ in demand, both in kind of demand and in location of demand. (a) Commodities differ in their capacity for

> receiving additional utility through transportation, as is well-known to be the case as between "low grade" goods such as sand and "high grade" goods such as glass ware -- the one does not "stand transportation" as well as the other. (b) Commodities also differ in the location of demand, being valued in different markets.[1]

Consequently, railroad firms which haul more than a single commodity or service more than a single pair of locations are producers of multiple products. The notion of homogeneous products, typically assumed in single product production theory, must be altered.

Multiple product production has important implications for firm production and marketing behavior. Identification of multiple output characteristics is required for selection of appropriate theoretical tools. Multiple product production may be mistaken for joint production or for simple product differentiation. Joint products imply an inevitable simultaneity in the technical production process. Classic examples of joint products are wool and mutton, and steel and smoke. Whether valued positively or negatively, each secondary product is formed as a "by-product" in the creation of the primary item. Joint products are technically interdependent.

Differentiated products tend to be similar outputs which require a deliberate decision to modify the nature, appearance, or image of articles to capture the interests of different groups of consumers. Differentiated products may be technically independent with branching of product lines typically initiated late in production processes. The distinction between multiple and differentiated products is subtle. The two differ only as a matter of degree and have no clear point of demarcation.

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[1]Lewis H. Haney, "Joint Costs with Especial Regard to Railways," Quarterly Journal of Economics, 30 (February, 1916), 235.

Multiple products differ from one another in their unique relationship to commodity markets. Multiple products are technically independent and bear no necessary relationship to one another, in use. Carriage of grain and automobiles may be accomplished simultaneously by the work of a single engine on a single track. However, there appears no reason grain hauling could not be accomplished without the movement of automobiles, as evidenced by unit train operations. Similarly, transport of grain from one location is not dependent upon grain movements from other locations. The decision to produce each railroad product of commodity and location characteristics must be made explicitly.

Production of multiple outputs in the presence of a single set of durable resources requires a theory which permits application of durable inputs to more than a single output. Clemens explains the motivation behind multiple output production.

> What the firm has to sell is not a product, or even a line of products, but rather its capacity to produce. Any idle piece of equipment, any unused technical knowledge or organizational resources possessed by the firm represent a challenge to the sales force and production manager. Any market reasonably accessible to the firm in which price is greater than marginal cost constitutes an invitation to invade. It is not necessary that the market be related to the firm's existing ones, although in view of management's experience it is desirable.[2]

Existing durable factors constitute this "capacity to produce." Durable inputs are not consumed in a single production period. When a portion of these inputs can be transferred between production processes, intrafirm competition is established between product lines for use of the set of stock resources. Too, there exists a possibility for

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[2]Eli W. Clemens, "Price Discrimination and the Multiple-Product Firm," Review of Economic Studies, 19 (1951-1952), 2.

short-run excess capacity with best use of resources to fulfill management objectives.[3] Production and investment theory applied later implies excess capacity in the longer term is not inconsistent with best use of resources. Consequently, excess capacity in itself is not a sufficient condition for disinvestment.

Considerable specificity in defining railroad outputs will be maintained. Composite products grouped by commodity type and by common origin or destination location are constructed to permit distinction of service to groups of similar commodities on a single roadway segment.

Inputs and Cost Relationships

Multiple output production implies use of a set of inputs at least a portion of which are not fully consumed in a single production period. Railroad inputs and cost relationships will be discussed together since the technical characteristics of each resource bear heavily upon the type of cost relationships management must deal with. First, a discussion of railroading as a decreasing cost industry will be directed toward placing this characteristic in perspective with time and levels of output aggregation. Secondly, inputs will be approached as interdependent units of resources with various degrees of durability. Short and long run time periods are abandoned in favor of variable lengths of run. Understanding the economic characteristics of each resource will allow development of a production function for railroading which considers the importance of various durable inputs.

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[3]Ralph W. Pfouts, "The Theory of Cost and Production in the Multi-Product Firm," Econometrica, 29 (October, 1961), 651.

Increasing and Decreasing Average Cost

Relationships between railroad cost and output depend upon the dimensions of time and product aggregation inherent in the definition of output units. Different output units are associated with different sets of avoidable or variable costs. In the short term when roadway plant and equipment stock are fixed, aggregations of ton-mile outputs may be defined in units of carloads or trainloads of service to particular commodity groups on particular lines. In the longer term when roadway plant and equipment stock are variable, an aggregation of ton-mile outputs may be defined in units of branch line enterprises. The choice of appropriate output unit to use in analysis depends upon the question to be resolved. For questions relating to private or social investment in branch lines, the branch line enterprise unit is applied. A brief digression on cost functions related to the various output units will help to place the notion of railroading as a decreasing cost industry into perspective.

Addition of one more car to a scheduled train may give rise to a small incremental cost. As long as power equipment and roadway resources used do not strain their respective capacities and an additional crew shift is not required, shadow prices of these resources are zero for the decision whether to service an additional carload unit. The marginal carload cost amounts to the opportunity cost of using movement equipment in the intended service and individual car handling charges incurred. The decision to add one more train to an existing railroad line must be evaluated with a much broader set of variable costs. Marginal trainload cost includes opportunity cost of power equipment and operating capital paid in labor and fuel, as well as opportunity cost of movement equipment.

In the short term, where existing power and movement equipment is underutilized, marginal cost of these resources is equal to their zero shadow prices. Incremental roadway expense is very small for passage of additional cars or trains. If the railroad firm experiences shortages of equipment or operating capital, added cars or added trains are provided at higher and higher marginal opportunity cost. The relationship of marginal cost to output depends upon the supply of the "bottleneck" resource. Rapidly rising marginal cost may be caused by equipment shortages even in the presence of excess roadway capacity.

Unavoidable roadway expense per carload or trainload unit, in the short run, is quite large at very low levels of traffic volume on branch lines. This average unavoidable expense declines continually as traffic output increases. Whether marginal cost lies above or below average cost is a matter for empirical resolution. The answer depends upon the level and rate of change of both average and marginal cost relationships.

Using aggregate firm data, Lorenz has demonstrated that fuller utilization of existing roadway facilities causes decreasing average costs in railroad production.[4] An inverse relation was discovered between operating expense per gross ton-mile and gross ton-miles per mile of roadway, for a cross section sample of railroad firms. The relationship does not describe directly the branch line average cost function.

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[4]M. O. Lorenz, "Cost and Value of Service in Railroad Rate-Making," Quarterly Journal of Economics, 30 (February, 1916), 216-219.

First, accounting procedures exclude measurement of equipment shadow prices. Secondly, data represent cost averages over entire firm operations, including both mainline and branch line operations.

Also using aggregate firm data on railroad costs, Borts has provided some evidence that marginal cost of carloads sometimes lies above and sometimes below average cost.[5] Estimates of railroad cost as functions of car miles and average length of haul per car were made for three firm size classes and three regions. While holding length of haul constant, carload marginal cost for large firms is greater than that for small firms, though the difference is not significant statistically. For Eastern railroads elasticity of cost with respect to carloads is predominantly greater than unity, that is, costs increase proportionally faster than output, evidence of increasing average cost. Finally average costs evaluated at mean carload levels within each firm size class are higher for larger firms and lower for smaller firms, indicating that minimum attainable carload unit cost for large companies is higher than for small firms. In several instances measured marginal cost lay above measured average cost, in the East. In the West, declining average cost and increasing marginal cost of carloads is notable. Both marginal and average carload cost relationships are falling as output increases, in the South. Borts' results cannot be used directly to make inferences about branch line cost functions. Borts' procedure, like that of Lorenz, does not account for equipment shadow prices and aggregate firm data used represent averages of mainline and branch line costs.

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[5]George H. Borts, "The Estimation of Rail Cost Functions," Econometrica, 28 (January, 1960), 108-131.

In the longer term when roadway plant and equipment stock become variable, one observes the incremental cost associated with additional branch line enterprises. A firm operating with excess equipment, managerial or financial capacity may maintain operations on a line with very low marginal cost. However, as capacity tightens, allocation of resources to the branch comes at increasing marginal opportunity cost of capital, management and equipment. Operating and investment capital must be obtained from ever more expensive sources. Management gives attention to the marginal branch at the expense of attention to other branch enterprises. As equipment utilization approaches capacity, railroad cars and engines are placed in service to the marginal branch at the expense of potential traffic generations on other branch enterprises. Financially insecure railroad firms with shortages of capital likely operate with increasing marginal cost of branch line enterprises. Though this presumption requires empirical verification, increasing long term marginal cost for branch line enterprises is assumed.

Resource Durability and Cost

The structure of costs within the railroad firm is marked by diverse input durability. In the economic sense, cost is the value of feasible alternatives foregone as a result of resource use decisions. Once decisions are made and implemented, the entire set of alternatives open to the firm is altered in dynamic interaction with the environment. W. A. Lewis has developed a useful dichotomy of costs which permits distinction between what are commonly called fixed and variable costs.[6]

[6]W. A. Lewis, "Fixed Costs," in Transport, ed. by Denys Munby (Baltimore: Penguin Books, Inc., 1968), pp. 61-97.

Costs are classified as escapable and inescapable. Given technical, institutional and market characteristics of individual inputs, degree of escapability is dependent upon time. For firms with numerous durable inputs of varying degrees of escapability, the notion of long run is rendered incapable of serving firm production and investment analysis. Interdependence of multiple durable inputs implies that as the life of any one element expires, the entire structure of assets will be affected. This suggests formation of an investment-disinvestment decision model which jointly treats all resources affected by a decision.

Costs which are wholly inescapable are not as prevalent as commonly imagined, though Lewis explains four categories of cost which cannot be avoided.

(a) some are inescapable in the short run but not in the long run;
(b) some are joint costs, and inescapable only in that sense;
(c) some are inescapable for small but not for large changes of output; and
(d) some are inescapable in all senses.[7]

Each category of railroad inputs will be discussed in relation to one or more of these descriptions, for only avoidable costs are relevant to the capital adjustment decision process.

The first type of unavoidable cost is that for which cost escaped currently may not be as great as cost escaped later. The decision problem becomes one of assessing immediate and ultimate savings in an environment of continually changing opportunities. Resources described in this category are contracted inputs and investments in durable assets.

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[7]Ibid., pp. 62-63.

Costs of contracted labor and fuel are to a degree inescapable short of contract expiration. Contract negotiation and Congressional action have made labor a durable resource. Resource saving mergers and abandonments have been effected at the costs of severence pay and relocation of affected workers. Only in the longer term, as workers reach retirement age, or an age at which early retirement is advantageous to both employee and employer, are these labor costs avoidable.

Costs associated with physical assets vary in degree of escapability over time. Some of the costs may be escaped immediately. Costs of operation can be escaped by not using equipment. Costs of ownership may be avoided through sale or salvage. However, if the present value of the equipment in operation, considering risk, is greater than the present value of operating costs and salvage value, currently escapable cost will not be as great as that avoided later. Most equipment and facilities are described in this manner. Railroad cars and engines, once purchased, may be put into service, sold, or kept in reserve. Costs of operation are escapable by disuse. Ownership costs are avoidable to a degree equal to salvage value. The same is true for building, terminal, traffic control, and roadway facilities. Each has a life unique to its technical nature and its salvage market, both of which are dynamic.

Joint costs are incurred by simultaneous use of a resource in production. These costs are not escapable by eliminating production of one product, for they continue with production of the other. Power units and movement units are separate. One engine may serve dozens of cars. Once a train is formed, marginal cost of adding another car may be small and the sum of the marginal costs does not equal total cost of owning and operating the engine. Expenses of ownership, maintenance and personnel cannot be allocated in proportion to ton-mile outputs. Back hauls may be treated similarly. When equipment runs on a branch between points A and B with uneven traffic, the added cost of carriage in the direction of traffic deficit is small, unless opportunity cost of equipment makes faster, empty returns more attractive.

Joint costs may become assignable to product groups where not identifiable by individual products. Collecting products by common origin or destination locations defines the group of railroad products originated or terminated on a particular branch line. On branches where overhead traffic is not present or where such traffic can be rerouted, full roadway, structure, and personnel costs are identifiable to the composite product. A portion of equipment rents and fuel expenses are also identifiable. To the extent that joint costs are allocable to products, they are escapable.

Lewis' third category of inescapable costs is similar to joint costs. There are some costs which cannot be allocated because they are indivisible. Indivisible costs differ from joint costs in that the former does not require simultaneous use of durable resources. Roadway, engines, cars, and freight stations may be used for various movements separately, such as, for composition of different trains at different times. Still, expenditures on these resources will not vary directly with ton-mile outputs. Marginal cost of using a freight car one more time or running over a track one more time may be small.

Buildings and many parts of roadway impose indivisible costs as each deteriorates with time rather than in proportion to ton-mile outputs. Buildings age as rapidly on light density branch lines as on mainlines. Railroad ties and fences succumb to natural forces with time rather than traffic. Snow and sand removal are random expenses. Of the entire roadway only steel rail and joints deteriorate in a reasonably direct way with traffic volume. For example, the Interstate Commerce Commission attributes just fifty-seven percent of total maintenance expenditures, for running track, as a traffic related expense.[8] Earlier, Acworth crudely estimated traffic related maintenance expense at about forty percent.[9]

Indivisible costs amount to the difference between total cost and the sum of output times marginal cost. Indivisible costs are described as inescapable for small but escapable for large changes in output. This means that reductions in train frequency and abandonment of branch operations are ways to escape indivisible costs while a single shipment order has no impact on indivisibles. Lewis notes that "whatever the indivisible unit, if the expenses attributable to it are escapable they must be covered if the unit is to be maintained."[10] This is to say that when opportunities arise to escape the expenses commonly thought of as fixed, revenues must cover such costs to keep the indivisible unit in service.

Expenses and revenues attributable to an indivisible unit must be considered in relation to the entire firm operation, not just those identified directly with the unit. Nove suggests the existence of internal economies as justification of cross-subsidization of enterprises

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[8]Interstate Commerce Commission, Railroad Carload Cost Scales by Territories for the Year 1970 (Washington, D.C.: Interstate Commerce Commission, 1973), p. 200.

[9]W. M. Acworth, The Elements of Railway Economics (Oxford: The Clarendon Press, 1905), pp. 34-35.

[10]Lewis, "Fixed Costs," p. 66.

within transportation firms.[11] According to Nove, one segment of roadway may be able to subsidize unprofitable feeder lines for traffic collection services provided. However, this approach isolates expenses and revenues to trackage units rather than traffic units and complicates the accounting procedure. Freight rates are charged to traffic units. When ton-mile traffic units are aggregated across commodities hauled to and from a common roadway link, the branch line enterprise is defined as a traffic unit for purposes of expense and revenue accounting. Calculation of both on-branch and off-branch expenses and revenues completely describes the influence of a particular branch line on an entire railroad company system.

The final category of inescapable costs are those which can never be escaped. These costs are related to items which are perfectly perishable or permanently durable and for which there exists no salvage market. Acworth provides a colorful survey of the resources used in developing roadway. Before rail can be laid rough surveys of alternative routes and intensive surveys of the selected route, legal negotiations with landowners and local authorities, and buying of land and paying of damages to adjacent land holders, are preliminary.

> The embankments and cuttings, the tunnels and viaducts, the bridges and platforms, the culverts and ballast, all are fixed to the spot forever. If the railway is a failure, they can never serve any other purpose where they are, not be taken up and employed elsewhere.[12]

These costs are variable prior to investment and are important to the investment decision. Once the investment has taken place, these costs

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[11]Alec Nove, "Internal Economies," Economic Journal 79 (December, 1969), 847-860.

[12]Acworth, Railway Economics, p. 12.

are considered sunk costs and play no role in further investment or disinvestment decision making.

Treating time as a continuum and multiple durable inputs as interdependent in production processes requires reassessment of all productive assets when a single contractual commitment or the life of a single asset expires. As one moves from the immediate production period to longer time frames, the definition of "fixed" becomes hazy as part of costs remains inescapable and part becomes escapable through salvage or disuse. These notions become important in development of a suitable production function including durable resources and in development of investment-disinvestment criteria.

Production and Investment

The decision by a railroad firm to abandon a right-of-way is a capital adjustment decision affecting long range production. The foregoing description of interdependent cost relationships requires production and investment-disinvestment functions which consider the continual interaction of all variable and durable resources. Conditions leading to contemplation of capital adjustment imply some discretion by management to vary stocks of durable inputs. A model allowing both flow and stock inputs to vary is needed to represent the relationship between production and investment. Brief development of a production-investment model will guide development of investment-disinvestment criteria for branch lines.

Vernon Smith has developed a stock-flow production function considering inputs of all degrees of durability.[13] Smith dismisses the capital service flow approach of converting stock assets into flow inputs on current account. Rather, output varies with the physical quantities of durable assets present in the production process. Durable resources are those which add value to the production process by their very "presence."

The stock-flow production function represents the highest level of output obtainable with applications of different levels and mixes of variable and durable inputs. For the moment assume a firm produces one output, y, with use of one variable and one durable input, x_1 and X_2, respectively. Express the firm's production function as $y = f(x_1, X_2)$.

Stock-flow production functions have been criticized severely for implicit assumptions of constant rates of utilization of durable inputs. Smith recognizes the potential for substituting durable factors for variable inputs, but explicitly disregards the substitutability of more intense use of a capital good for marginal increases in its stock, for lack of empirical support.[14] Idachaba argues that rates of utilization of stock resources may act as substitutes for additions to these stocks.[15] This implies a production function of the form $y = f(x_1, X_2, \Theta_2)$ where Θ_2 is an index of capital service flows from marginal changes in the rate of utilization of durable factor X_2. Input price

[13]Vernon L. Smith, Investment and Production (Cambridge: Harvard University Press, 1961), Chapter 3.

[14]Ibid., p. 66.

[15]Francis Sulemanu Idachaba, "Rate of Use, Investment and Disinvestment" (paper presented in the Department of Agricultural Economics, Michigan State University, 1972, Mimeographed).

attached to Θ_2 is the user cost associated with varying rates of utilization.

The approach of Idachaba makes development of empirically useful production-investment models unnecessarily difficult. Measurement of user cost remains a difficulty not yet overcome in regard to railroad durable inputs. Paucity of measurement techniques is notable with continued application of highly complex cost allocation schemes perpetuated by Interstate Commerce Commission accounting methods.

Investment models are consulted previous to capital installations or liquidations. Consequently enterpreneurs will be making demand forecasts based upon varying quality of information about the future. Definition of stock inputs and associated costs may be made to conform with one or a combination of rates of output assigned to the various portions of the time horizon. A single type of capital good may be defined with characteristics of different output rate and different length of life, as often done in programming techniques. For example, one may use the production function $y = f(x_1, X_2, X_3)$ where X_3 is the same machine as X_2 but used at a different constant rate. Alternatively, if a probability distribution of future demands exists, a mean rate of utilization may be applied and the best input mix may be selected accordingly. If the decision maker is completely uncertain about the future, he may wish to select a stock of highly flexible durable resources. As long as a mean rate of utilization or a level of insurance through flexibility is understood, rate of use of stock resources need not be entered as a distinct input. Idachaba's argument is useful to modify the approach to investment modeling to allow substitution of rate of use for stocks of a physical input.

When planning the proper input mix one must have information on costs of resources and demand characteristics. With fixed output, the firm may wish to minimize cost; if output varies to meet demand the firm may wish to maximize profits. Assume a cost function

$$C = w_1x_1 + \frac{rW_2X_2}{1-e^{-rT}}$$

where w_1 is the price of variable input x_1, and $\frac{rW_2}{1-e^{-rT}}$ is the discounted depreciation cost of a durable good originally priced at W_2 where r is the opportunity cost of capital and T is the planning horizon. Also assume a constant value of capital through time, that is, $\frac{dW_2(t)}{dt} = 0$ where t denotes time.

With demand $p = g(y)$ a profit maximizing firm accepting constant prices will seek to obtain an output mix maximizing profit

$$\Pi = py - w_1x_1 - \frac{rW_2X_2}{1-e^{-rT}} .$$

Setting first order conditions equal to zero

$$\frac{\delta\Pi}{\delta x_1} = pf_1 - w_1 = 0$$

$$\frac{\delta\Pi}{\delta X_2} = pf_2 - \frac{rW_2}{1-e^{-rT}} = 0$$

where f_1 and f_2 are marginal products of x_1 and X_2, respectively. These conditions imply a marginal rate of technical substitution between variable and durable resources of

$$\frac{f_1}{f_2} = \frac{w_1(1-e^{-rT})}{rW_2}$$

revealing that longer planning horizons tend to favor a greater proportion of investment in durable resources. Solving first order conditions simultaneously, one can obtain derived demand functions for each resource of

$$x_1 = x_1(p, w_1, W_2, r, T)$$

$$X_2 = X_2(p, w_1, W_2, r, T).$$

Allowing the planning horizon to be fixed by management and assuming interest rate is determined exogenously to the firm, the two derived demand equations can be solved for the two unknown levels of inputs x_1 and X_2, with knowledge of input prices, w_1 and W_2.

Once capital resources have been installed, the stock-flow model is of no use since durable factors are no longer variable. If demand increases calling for output above capacity, a similar production function is constructed for consideration of plant expansion. The expansion function will differ from the former model in being conditioned by previous investments. The new function may appear as

$$y = h(x_1, X_3 | X_2^o)$$

where X_3 may represent increased rate of output of current stocks, additional production lines, or completely new facilities.

Also once capital resources have been installed, decreases in durable assets are not possible without returning to a stock-flow production function for guidance toward best disinvestments. Contractions, too, are conditioned by previous investment actions. Smith discusses disinvestment in quite a different context than investment, however. While investments may occur in increments as demand increases, disinvestments are considered appropriate only when marginal revenue product for the durable resource falls to zero, when maintenance costs are assumed away. Smith concludes, therefore, that optimal investment planning may lead to over-capacity as demand shifts away from the subject product.[16]

Johnson and Quance modify the stock-flow approach with inclusion of the salvage alternative.[17] The same production and cost functions may be employed. Investments and disinvestments are again conditioned on previous investment actions. Assuming a salvage value, $P^S_{X_2}$, for the durable input exists somewhere above zero and the cost of acquiring still more of the durable factor, $P^A_{X_2}$, lies above salvage value, that is,

$$0 \leq P^S_{X_2} \leq P^A_{X_2} \leq \infty$$

the firm will seek to adjust durable assets in a manner to maximize net gain, G, relative to the current position. This model is quite similar to a partial budgeting approach in that only those factors which are affected by a possible change are considered. The gain function appears as

$$G = p(y - y^o) - a(X_2 - X_2^o)$$

where the first term on the right represents the revenue generated or lost by the change in output resulting from capital adjustment and the second term depicts changes in cost. When $(X_2 - X_2^o) > 0$ net additions

[16]Smith, Investment and Production, p. 15.

[17]Glenn L. Johnson and C. Leroy Quance, The Overproduction Trap in U.S. Agriculture (Baltimore: The Johns Hopkins University Press, 1972), pp. 22-40, 185-196.

are made to durable factors and $a = P^A_{X_2}$, the acquisition price. When $(X_2 - X_2^o) < 0$ disinvestment occurs and $a = P^S_{X_2}$, the salvage price. The presence of a double negative sign makes total salvage income a positive value. When $(X_2 - X_2^o) = 0$, no adjustment of resource X_2 is undertaken implying the factor holds a value in production greater than salvage price but not great enough to warrant acquisition of more of the capital good, that is,

$$P^S_{X_2} < a < P^A_{X_2} .$$

Gain is maximized subject to inequality conditions specifying that the final stock of asset applied be a positive quantity and that no more of the factor be sold than what is originally on hand.

Johnson and Quance, too, conclude that optimum investment behavior can lead to overcapacity as long as salvage and acquisition prices of capital goods diverge. Though demand shifts may prevent entrepreneurs from realizing returns covering full initial costs of durable factors, these items will be employed in the firm as long as marginal revenue product is greater than salvage value. Implications are that firms make ready supply responses to increasing demand conditions, but insufficiently contract in the face of demand decreases.

Investment-Disinvestment Criteria

The Johnson-Quance gain function and Smith's stock-flow production function conditioned by previous investments are nearly indistinguishable. The form of the gain function is most convenient for treating just those factors affected by capital adjustments. Assume railroad management seeks to maximize net revenues over a specified time period. Assume also that the railroad firm was established years ago and is currently producing transportation services with a stock of physical plant and equipment. Though management is assumed unconstrained by regulation, prices will be assumed fixed for now.

The railroad production function relates five composite inputs to the output of numerous transportation products. Outputs are aggregated by commodity type and common location of either origin or termination. Inputs include labor, L, fuel, F, railroad cars, C, engines, E, and roadway with associated terminals and control systems, R. The production function for transporting commodity i either to or from railroad station k is

$$y_{ik} = f(L,F,C,E,R)$$

where y represents ton or ton-mile quantities of railroad service.

Any perceptible change in relative output or input prices will cause management to review its stock of plant and equipment for appropriateness in meeting the firm's objective. Adjustment may take place by acquiring or selling cars, engines, or roadway capacity. Opportunities for net gain through capital adjustment appear as

$$G = \sum_k \sum_i P_{ik} (y_{ik} - y^o_{ik}) + \sum_j \sum_v P^S_{jv} C_{jv} - \sum_j \sum_v P^A_{jv} C_{jv}$$
$$+ \sum_e \sum_w P^S_{ew} E_{ew} - \sum_e \sum_w P^A_{ew} E_{ew} + \sum_k \sum_{\gamma^-} P^S_{\gamma-k} R_{\gamma-k}$$
$$- \sum_k \sum_{\gamma+} P^A_{\gamma+k} R_{\gamma+k} + \sum_k P^L_{\gamma_o k} R_{\gamma_o k}$$

where

P_{ik} = Discounted unit operating surplus of transport service to commodity i to or from location k (dollars/ton),

$(y_{ik} - y_{ik}^{o})$ = Change in annual quantity of service rendered for commodity i at station k (tons),

P_{jv}^{S}, P_{jv}^{A} = Salvage and acquisition prices of railroad car type j, vintage v (dollars),

C_{jv} = Number of railroad cars type j, vintage v (units),

P_{ew}^{S}, P_{ew}^{A} = Salvage and acquisition prices of engines of power and type e, vintage w (dollars),

E_{ew} = Number of engines of power and type e, vintage w (units),

$P_{\gamma-k}^{S}, P_{\gamma+k}^{A}, P_{\gamma_o k}^{L}$ = Salvage, acquisition, and liquidation prices of roadway of capacity γ, to station k (dollars), and

$R_{\gamma k}$ = Presence of roadway of capacity γ to station k.

The gain model allows for sale of old or obsolescent equipment and acquisition of new, simultaneously. Railroad firms may consider abandonment of one rail link while comtemplating an extension elsewhere. Some salvage prices may be zero and some acquisition prices infinite where markets do not currently exist.

The first term of the gain function, $\sum_k \sum_i P_{ik} (y_{ik} - y_{ik}^{o})$, defines the difference in net operating revenues attributable to sales of transportation services before and after capital adjustment, discounted over the planning horizon. Depending upon the net effects of capital adjustment upon traffic generation, this term may be either positive or negative.

The second and third terms of the gain equation, $\sum_j \sum_v P_{jv}^{S} C_{jv}$ and $\sum_j \sum_v P_{jv}^{A} C_{jv}$, respectively, represent salvage and acquisition opportunities for the many kinds of cars of different ages. The Interstate Commerce Commission reports operating costs for seventeen railroad car types. Salvage price, P_{jv}^{S}, may be the value gained either from sale of cars or from reduced equipment maintenance standards. An example of the latter is suspension of tight door and floor maintenance on boxcars, necessary for grain shipment but not essential for general cargo. Similarly, acquisition may reflect the cost of modifying car service characteristics as well as buying new or used cars.

Net gains from salvage and acquisition of motive power units, $\sum_e \sum_w P^S_{ew} E_{ew}$ and $\sum_e \sum_w P^A_{ew} E_{ew}$, respectively, are similar in description to railroad car adjustments. Salvage and acquisition prices may represent engine modifications as well as sale or purchase. These prices may also reflect the discounted cost of fuel consumption of each alternative over its planned life. Rate of fuel consumption has many determinants. Where an engine is destined for use in a particular region with a predetermined mean train size, engine types can be compared for fuel use.

The term $\sum_k \sum_{\gamma-} P^S_{\gamma-k} R_{\gamma-k}$ represents net gain obtainable by reducing roadway capacity from γ to $\gamma-$ on the segment leading to station k in the direction of the terminus. Capacity reduction may be achieved by various means. Signal systems may be salvaged, reducing speed and train capacity. Sidings and other than main tracks may be removed and materials sold for scrap or reused elsewhere. Maintenance standards may be reduced allowing the quality of track and roadbed to deteriorate. Neglecting maintenance results in depreciation and maintenance cost savings, in trade for increased costs of operation due to slower traffic speeds and more frequent derailments. The gain from all capacity reduction is the sum of discounted net gains from sales of auxiliary facilities and maintenance cost savings, summed over all links being adjusted.

Acquisition cost of increasing roadway capacities from γ to $\gamma+$, $\sum_k \sum_{\gamma+} P^A_{\gamma+k} R_{\gamma+k}$, represents cost of adding auxiliary facilities, increasing maintenance standards, and acquiring new rights-of-way. Acquisition prices of the latter are considerably higher than salvage prices due to the high, permanently inescapable costs of surveying, cutting and clearing land, and legal transactions.

The final term of the gain function, $\sum_k P^L_{\gamma_o k} R_{\gamma_o k}$, represents the net value to the railroad firm from liquidating a segment of roadway already of minimum capacity, γ_o. Salvage alternatives include sale of an enterprise to another firm with intentions to continue operations or dismantling physical structures for separate sale. In a narrow sense the railroad firm seeking to abandon a line may be indifferent to disintegration and sale as a short-line operation. In a broader sense of regional transportation service demand, decision makers may discriminate. Where traffic from the abandoned line is likely to be diverted to another station on that company's lines, physical disintegration may be preferred to avoid forfeiture of origin-termination charges to a short-line operation. Where traffic from the abandoned line is likely to be diverted to another mode, sale as a short-line may serve to retain a portion of freight revenues.

Total liquidation price, $P^L_{\gamma_o k}$, is the present value of saving all costs associated with the presence of the rail line, independent of traffic. Costs associated with traffic may be avoided by not operating trains; costs associated with roadway may be avoided by abandonment. Roadway liquidation price may be defined by the following identity.

$$P^L_{\gamma_o k} \equiv S + T + .43M - J$$

where

S = Salvage value of land, track, and structures less dismantling cost,

T = Discounted present value of *ad valorem* taxes,

M = Discounted present value of maintenance of way and structures expenses, and

J = Discounted present value of rental income from joint trackage rights and use of pole, ground, and air space.

Total maintenance expenses are multiplied by the constant 0.43 to represent only the component of these costs not related to traffic. This constant was issued by the Section of Cost Finding of the ICC's Bureau of Accounts, resulting from a five-year, cross sectional analysis of expenses of all Class I line-haul railroads for the period 1966-1970.[18]

Maximization of the gain function is subject to several constraints of feasibility. Post adjustment resource stocks, denoted with absence of superscript, may not exceed original stocks less the amount salvaged, plus the amount required. No more of a resource may be salvaged than originally held in stock. These restrictions appear as

$$C_j^O - C_j^S + C_j^A \geq C_j$$

$$E_e^O - E_e^S + E_e^A \geq E_e$$

$$R_{\gamma k}^O - R_{\gamma_O k}^L - R_{\gamma - k}^S + R_{\gamma + k}^A \geq R_{\gamma k}$$

$$C_j^O \geq C_j^S$$

$$E_e^O \geq E_e^S$$

$$R_{\gamma k}^O \geq R_{\gamma - k}^S$$

$$R_{\gamma_O k}^O \geq R_{\gamma_O k}^L$$

[18]Interstate Commerce Commission, Carload Cost Scales, p. 200.

The nature of multiple output production and the inclusion of liquidation alternatives require an optimizing technique which will treat inequality constraints and boundary solutions. The conventional Lagrangian multiplier technique is limited to interior solutions implying no specialization in production and no liquidation alternatives. Application of the Kuhn-Tucker theorem will provide a set of necessary and sufficient conditions for maximizing the gain function. Demonstrations of the technique as applied to firm production and cost problems have been performed by Pfouts for cost minimization and by Naylor for profit maximization.[19] Naylor's explanation of Kuhn-Tucker conditions for maximization will be summarized before application to the railroad capital adjustment gain function.

The Kuhn-Tucker theorem is a tool with which to find extreme values of a function such as

$$g = g(X_1,\ldots,X_n)$$

subject to constraints which may be either equalities or inequalities, as

$$h_r(X_1,\ldots,X_n) \geq 0 \qquad r = 1,\ldots,q$$

For a maximization problem one assumes the objective function and constraints to be concave to the origin and differentiable. Minimization requires convex, differentiable functions. Further, maximization requires that the Lagrangian expression $L(X,\lambda)$ be a concave expression of X at any particular value of λ and a convex function of λ at any value of X.

[19]Ralph W. Pfouts, "The Theory of Cost and Production in the Multi-Product Firm," Econometrica, 29 (October, 1961), 650-658. Thomas H. Naylor, "A Kuhn-Tucker Model of the Multi-Product, Multi-Factor Firm," Southern Economic Journal, 31 (April, 1965), 324-330.

The latter assumption guards against a single point appearing on the frontier of the constraints.

First a Lagrangian form of the constrained objective function is formed as

$$L(X_i, \lambda_r) = g(X_i) + \sum_{r=1}^{q} \lambda_r h_r(X_i)$$

$$X_i \geq 0 \qquad i = 1,\ldots,n$$

$$\lambda_r \geq 0 \qquad r = 1,\ldots,q$$

It is both necessary and sufficient for existence of a maximum that a saddle-point exist at the extreme value of $L(X_i,\lambda_r)$. The Kuhn-Tucker theorem states that under the above conditions, for a saddle-point to exist, the following necessary and sufficient conditions must hold.

$$\left.\frac{\delta L}{\delta X_i}\right|_{X_i = X_i^o} \leq 0 \qquad i = 1,\ldots,n$$

$$\sum_{i=1}^{n} \left.\frac{\delta L}{\delta X_i}\right|_{X_i = X_1^o} \cdot X_i^o = 0$$

$$X_i^o \geq 0 \qquad i = 1,\ldots,n$$

$$\left.\frac{\delta L}{\delta \lambda_r}\right|_{\lambda_r = \lambda_r^o} \geq 0 \qquad r = 1,\ldots,q$$

$$\sum_{r=1}^{n} \left.\frac{\delta L}{\delta \lambda_r}\right|_{\lambda_r = \lambda_r^o} \cdot \lambda_r^o = 0$$

$$\lambda_r^o \geq 0 \qquad r = 1,\ldots,q$$

The first condition produces a "corner" solution when the inequality holds, that is, no amount of X_i enters the solution in the presence of the inequality. Variable X_i does enter the final solution when the equality holds. The second condition is an either-or statement showing that either the best amount of X_i to include is zero or a quantity consistent with the marginal conditions of the Lagrange expression. The fourth condition assumes the equality only when the associated constraint is limiting. Conditions three and six require non-negative quantities of all variables and multipliers.

Applying the procedure to maximize the railroad capital adjustment gain function, the following Lagrangian expression is formed.

$$
\begin{aligned}
L = & \sum_k \sum_i P_{ik} (y_{ik} - y^o_{ik}) + \sum_j \sum_v P^S_{jv} C_{jv} \\
& - \sum_j \sum_v P^A_{jv} C_{jv} + \sum_e \sum_w P^S_{ew} E_{ew} - \sum_e \sum_w P^A_{ew} E_{ew} \\
& + \sum_k \sum_{\gamma-} P^S_{\gamma-k} R_{\gamma-k} - \sum_k \sum_{\gamma+} P^A_{\gamma+k} R_{\gamma+k} + \sum_k P^L_{\gamma_o k} R_{\gamma_o k} \\
& + \sum_j \lambda_j (C^o_j - C^S_j + C^A_j - C_j) + \sum_e \lambda_e (E^o_e - E^S_e + E^A_e - E_e) \\
& + \sum_k \lambda_{\gamma k} (R^o_{\gamma k} - R^L_{\gamma_o k} - R^S_{\gamma-k} + R^A_{\gamma+k} - R_{\gamma k}) \\
& + \sum_j \mu_j (C^o_j - C^S_j) + \sum_e \mu_e (E^o_e - E^S_e) \\
& + \sum_k \mu_{\gamma k} (R^o_{\gamma k} - R^S_{\gamma-k}) + \sum_k \mu_k (R^o_k - R^L_{\gamma_o k})
\end{aligned}
$$

where the λ's represent shadow prices of restricted resources and the μ's equal salvage prices when the respective constraints become effective. Location of a saddle-point for the function will be necessary and sufficient for maximization. Satisfaction of Kuhn-Tucker conditions is necessary and sufficient for location of a saddle-point. Kuhn-Tucker conditions are included here only for roadway elements. This procedure is proper when roadway adjustments have no significant implications for appropriate stocks of power and movement equipment. Since the concern of this research is with lightly traveled lines, abandonments are assumed not to affect optimal levels of rolling stock. For broader system adjustments the entire model must be employed to account for the interdependence of multiple durable inputs. Kuhn-Tucker conditions for roadway inputs require

$$\frac{\delta L}{\delta R_k} = P_{ik}\frac{\delta y_{ik}}{\delta R_k} - \lambda_{\gamma k} \leq 0; \; \frac{\delta L}{\delta R_k} R_k = 0; \; R_k \geq 0$$

$$\frac{\delta L}{\delta R^L_{\gamma_o k}} = P^L_{\gamma_o k} - \lambda_{\gamma k} - \mu_k \leq 0; \; \frac{\delta L}{\delta R^L_{\gamma_o k}} R^L_{\gamma_o k} = 0; \; R^L_{\gamma_o k} \geq 0$$

$$\frac{\delta L}{\delta R_{\gamma - k}} = P^S_{\gamma - k} - \lambda_{\gamma k} - \mu_{\gamma k} \leq 0; \; \frac{\delta L}{\delta R_{\gamma - k}} R_{\gamma - k} = 0; \; R_{\gamma - k} \geq 0$$

$$\frac{\delta L}{\delta R_{\gamma + k}} = \lambda_{\gamma k} - P^A_{\gamma + k} \leq 0; \; \frac{\delta L}{\delta R_{\gamma + k}} R_{\gamma + k} = 0; \; R_{\gamma + k} \geq 0$$

The second condition for each roadway input states an either-or condition. Either marginal gain equals marginal cost, describing an action situation and setting the partial derivation to zero, or marginal gain is less than marginal opportunity cost, resulting in zero use of the factor. The third condition for each factor maintains non-negative quantities of all factors in the solution.

The first condition for each factor provides investment-disinvestment guidance criteria. Multipliers $\lambda_{\gamma k}$ are shadow prices of marginal units of roadway inputs of capacity γ at station k. In other words, the $\lambda_{\gamma k}$ denote the value of marginal roadway operations in the production process. As long as no more of a roadway element is sold than exists μ_k, $\mu_{\gamma k} = 0$. Summarizing the Kuhn-Tucker conditions, without excessive salvage activities, marginal revenue product may fall into one of four marginal factor cost intervals.

$$P^L_{\gamma_o k} \leq P^S_{\gamma - k} \leq \lambda_{\gamma k} \leq P^A_{\gamma + k}.$$

Marginal revenue product is marginal revenue times marginal product. Where rail freight rates are fixed, as assumed here, net marginal revenue equals rail service price adjusted for associated costs of operation. Marginal product is the output generated by the marginal unit of input. A marginal unit of roadway is a line segment leading to a revenue generating point, a station, in the direction of the line terminus. Thus, marginal product is total output from a marginal unit of roadway. Marginal revenue product is, then, the total net revenue accruing to the railroad firm from traffic originating or terminating on the marginal roadway segment.

If marginal revenue product of line k is equal to or greater than the marginal cost of building roadway capacity to station k, the line will be improved. The term $P^A_{\gamma + k}$ represents an ordered array of costs of capacity acquisition opportunities. Secondly, if marginal revenue product is equal to or less than the marginal net gain of reducing roadway capacity to station k, auxiliary facilities will be sold or maintenance standards reduced. The term $P^S_{\gamma - k}$ represents an ordered array of values of capacity salvage opportunities. When marginal revenue product of roadway leading to station k is equal to or less than the associated liquidation value, $P^L_{\gamma_o k}$, the line will be sold to another entrepreneur or dismantled. Only one such best alternative exists, considering sales value and diversion of traffic. Finally, if marginal revenue product is less than capacity acquisition price and greater than capacity salvage value, roadway will be left in its current condition for continued operation.

The Bound of Market Supply

The criteria for roadway investment and disinvestment reveal the boundary for voluntary market provision of railroad service. When the present value of expected net operating revenues, on a particular roadway segment, falls short of net income obtainable by liquidating the enterprise and investing resources elsewhere, market forces urge abandonment. This does not necessarily mean abandonment should be implemented. Measurements of net revenue and liquidation price reflect only financially effective desires articulated in the market by suppliers of factors and purchasers of services. Where continued operation of lines holds positive associated values not expressed in the market communication system, the boundary of social provision may be more broad than that of the market. Development of these concepts will be deferred to Chapter V.

The investment-disinvestment criteria previously constructed do provide guidance for public action. If one assumes that public agencies act as collective agents to articulate demands not effectively expressed in the market and that public action operates to encourage, rather than force, continued socially desirable railroad service, then public action will be designed to neutralize market pressures urging abandonment. This assumes continued application of the Brooks-Scanlon doctrine of nonconfiscatory public action, introduced in Chapter II. The abandonment criterion, then, serves to measure the degree of public remuneration necessary to make maintenance of a roadway segment the best opportunity for a railroad company. This measure may serve to guide federal and state rail line subsidy programs established under the Regional Rail Reorganization Act of 1973.

The function of decision criteria is to separate an entire decision space into clearly defined, mutually exclusive regions. The abandonment criterion divides the space of all possible decisions into abandonment and nonabandonment alternatives. To prevent abandonment, discounted net revenue generated on marginal link k must be greater than or equal to liquidation value of the line, that is

$$\sum_i P_{ik}\, y_{ik} \geq P^L_{Y_0}k$$

where P_{ik} is a set of discounted prices of rail service net of operating cost, to commodity i on link k, and y_{ik} is the amount of service expected to be produced for commodity i on link k. The left-hand term is the current value of expected net revenue to be generated by the market. The right-hand term is the value of the highest liquidation alternative available to the railroad.

The difference in these values represents the minimum present value of subsidy, U_0, necessary to encourage voluntary maintenance of roadway, that is,

$$U_o = P^L_{\gamma_o} k - \sum_i p_{ik}\, y_{ik}.$$

When U_o is less than zero, that is, when revenues from operation are greater than income from the salvage alternative, no subsidy is required. The market will support the rail line enterprise and external net benefits will be enjoyed without collective charge. When U_o becomes positive, either a lump sum subsidy of size U_o or an annual subsidy payment, U_a, must be provided to encourage retention of the line, where

$$U_a = \Psi(P^L_{\gamma_o} k - \sum_i p_{ik}\, y_{ik}).$$

This subsidy estimate assumes an agreement of an indefinite term and discount rate Ψ. The annual subsidy computed in this way amounts to a public agency giving the railroad a bond of value U_o with an annual coupon with interest rate Ψ.

Determining whether such a subsidy is warranted requires answer to the following question. Do net benefits excluded from market accounting exceed the price of subsidy? Answer to this question requires definition of the social bound to rail roadway provision which will be developed in Chapter V. However, procedures for estimating the level of magnitude of required subsidy need not be postponed.

Operationalizing the Abandonment Criterion

Application of roadway disinvestment criteria requires estimation of discounted net operating revenue attributable to a marginal roadway link and salvage prices for each capacity reducing opportunity. Abandonment typically is activated only on roadway of lowest possible capacity with single track, low maintenance standards, and lacking traffic control systems. These lines generally lead to end points of operating divisions making bridge traffic an insignificant contributor to branch revenues. Despite these common characteristics, railroad lines considered for abandonment are not homogeneous. Each has a unique set of cost and salvage price characteristics which require individual treatment in designing effective subsidies. The abandonment criterion, in operation, cannot be reduced to a simple formula with parameters defined. A procedure for using the criterion will be developed here. Also some estimates will be made to gain an understanding of the level of magnitude expected for various elements composing the criterion. Procedures for estimating roadway liquidation value will be addressed first, followed by discussion of net revenue measurement.

Recall that roadway liquidation value is composed of present values of several elements, net salvage value of materials and land, ad valorem tax savings, the portion of maintenance expenditures not associated with traffic and net losses of joint facility rents, that is

$$P^L_{\gamma_o k} \equiv S + T + .43\,M - J.$$

The value of each component varies considerably between railroad companies and between rail lines. Thirty-two Interstate Commerce Commission questionnaires, required of railroads seeking line abandonments, were reviewed to obtain information on salvage values, normal maintenance costs, rehabilitation expenses required to continue operations and net revenues for the last three years of operation before application. All cases were applications to abandon roadway links in Michigan in the period 1968 through 1972. Magnitudes of some liquidation price components were obtained by making rough estimates from questionnaire data.

Three elements make this liquidation value identity unique for each roadway segment, value of land sales, joint facility rents, and rehabilitation cost. Land values vary widely depending upon location. Of the thirty-two questionnaires supporting rail line abandonment applications, fourteen identified the value of land sales as a distinct item. Within these fourteen cases land value per mile ranged from $18 in a sparsely populated portion of Michigan's Upper Peninsula to $25,000 on a four and a half mile segment just beyond the limits of Detroit, Michigan. The mean value of land per mile for the fourteen cases was $3,949 while the median values for the even numbered sample were $414 and $419. Railroad land abandoned in cities is often highly valued commercial property. In undeveloped areas rights of way may have little value.

Joint facility rents refer to income received by the roadway owner from other users of the line. These rents depend upon contracts entered into with other railroads under ICC supervision. Of the thirty-two abandonment cases studied, only two involved joint trackage rights.

Rehabilitation expenses are accumulated maintenance expenses necessary to rebuild neglected roadway. These expenses are avoidable through abandonment, but usually necessary for continued operation. The history of maintenance neglect, number of bridges, type of roadway base, and climate all affect the level of expense required to reconstruct roadway. Twenty-one of the thirty-two abandonment questionnaires observed reported estimated rehabilitation cost. Figures ranged from $11,669 to $77,586 per mile for reconstruction, with a mean of $23,805 per mile and median of $30,703 per mile. Rehabilitation cost estimates are frequently challenged by protestants in ICC abandonment hearings for representing renewal to a standard far above that necessary for local service. Even if these estimates are high, rehabilitation may well require substantial amounts of resources.

Ad valorem taxes do not represent an element of liquidation value which is unique to lines, but ad valorem taxes are not amenable to reliable estimation, in Michigan. In 1905, Michigan became one of the first states to centralize property tax collection for railroads.[20] The Michigan formula for valuation of railroad property is a complex assessment of total company net worth prorated to Michigan by a series of methods. Capitalized earnings are prorated by the proportion of system ton-miles produced in the state. Market values of engines and cars are prorated by proportions of engine miles and car-miles operated in the state, respectively. Half of the total net worth apportioned to Michigan is subject to a rate of taxation determined by the State Tax Commission and applied similarly to all railroads. The tax rate has grown steadily from 37.6 mills, in 1965, to 49.1 mills, in 1973. Consequently, property taxes cannot be apportioned to roadway segments in proportion to length. Indeed, the railroad tax unit of the Michigan Department of the Treasury has no means by which to estimate ad valorem taxes attributable to individual railroad links.

Two liquidation price elements reported in ICC abandonment questionnaires bear some regularity, net material salvage value and annual maintenance cost. These values, too, vary considerably between line segments in a manner preventing precise estimates with a general formula.

[20]Michigan Public Act 1905, No. 282, as amended by Public Act 1953, No. 30.

However, estimators of these elements are fruitful for understanding the approximate value of resources occupied in rail roadway.

Net material salvage value is the difference between gross salvage value and cost of dismantling roadway and structures. Results of testing regression estimators for data included in twenty-three abandonment questionnaires are reported in Table 6. The purpose of this exercise is to provide readily useful estimators to roughly calculate levels of magnitude of liquidation price elements.

Results of the simple estimators show that most of the variation in gross salvage value and removal cost can be explained by length of the line segment and location. The first three equations reveal a nearly linear relationship between gross salvage value and length of line. Equation 5 shows that removal cost increases at a declining rate as length of line increases. The net result suggests some economy in removing longer roadway segments. Gross material salvage value does not vary significantly between locations, though cost of removal is significantly less in the Upper Peninsula.

Estimators one and four of Table 6 will be used to calculate gross material salvage value and removal cost, respectively. These estimators bear the lowest standard errors, thereby providing the most reliable predictions. If the market value for materials and the cost of removal are independent of one another, expected net material salvage values can be estimated as the differences in predicted gross salvage value and removal cost. Net material salvage value estimates for segments of mean length are shown in Table 7. These estimates must be used carefully since standard errors of estimates are quite high. Where gross salvage value and removal cost are independent, standard error of net

Table 6. Estimates for Gross Material Salvage Value and Removal Cost for Twenty-Three Abandonment Applications Tendered For Michigan Rail Lines, 1968-1972

	Dependent Variable	Length	$(Length)^2$	$(Length)^3$	Upper Peninsula	R^2	Standard Error of Estimate
1.	Gross Salvage Value	1,634.71 (4,391.72)	433.97 (243.96)	-4.90 (3.10)	-26,788.85 (41,702.21)	0.886	85,325.92
2.	Gross Salvage Value	7,542.60** (2,375.14)	56.14 (48.24)		-25,680.01 (43,149.79)	0.872	88,300.31
3.	Gross Salvage Value	9,962.80** (1,156.40)			-31,525.18 (43,200.10)	0.863	89,008.37
4.	Removal Cost	5,504.69** (1,618.33)	89.21 (89.58)	-2.18 (1.14)	-51,234.82** (15,141.02)	0.924	30,940.24
5.	Removal Cost	8,163.34** (891.68)	-79.65** (18.08)		-50,959.90** (16,124.74)	0.910	32,951.90
6.	Removal Cost	4,719.32** (587.41)			-42,391.96 (21,927.22)	0.822	45,139.20

Mean length for the twenty-three cases is 17.66 miles.

material salvage value is $90,762 for the mean length roadway segment, or $5,139 per mile.

Table 7. Estimates of Net Material Salvage Value for the Mean Length of Twenty-Three Line Segments Under Abandonment Application, 1968-1972

Item	Lower Peninsula		Upper Peninsula	
	Total	Per Mile	Total	Per Mile
Gross Material Salvage Value	$137,226	$7,770	$110,437	$6,254
Removal Cost	$113,028	$6,400	$ 61,794	$3,499
Net Material Salvage Value	$ 24,198	$1,370	$ 48,643	$2,754

Mean Length is 17.66 miles.

Normal annual maintenance cost for roadway can also be estimated roughly. Normal annual maintenance cost is that expense incurred in keeping a line at a constant repair standard, after being rehabilitated to the standard. An estimate of this value was provided in twenty of the ICC questionnaires attached to abandonment dockets. Estimators are constructed similar to those for salvage value; results are reported in Table 8. Most of the variation in maintenance cost can be explained by length of line. Line location appears to be an unimportant determinant of maintenance cost, within the state.

Equation one of Table 8 will provide a rough estimator of maintenance cost. At mean length of 13.75 miles, annual maintenance cost is approximately 41,409.82 or 3,012 per mile, in the Lower Peninsula. This level of magnitude appears reasonable compared to average running track maintenance expenditures for the entire systems of the Norfolk and

TABLE 8. Estimates of Normal Annual Maintenance Cost for Twenty Michigan Rail Lines Under Abandonment Application, 1968-1972

Dependent Variable	Length	$(Length)^2$	$(Length)^3$	Upper Peninsula	R^2	Standard Error of Estimate
1. Maintenance Cost	707.45** (131.63)	-41.94** (13.07)	0.64* (0.26)	1,199.30 (1,345.70)	0.813	1,415.10
2. Maintenance Cost	426.30** (67.16)	-11.01** (2.19)		21.31 (1,416.00)	0.746	1,599.87
3. Maintenance Cost	110.82** (37.06)			-1,540.98 (2,119.14)	0.366	2,453.95

Mean length is 13.75 miles.

Western Railroad and the Chesapeake and Ohio Railroad, two financially healthy companies operating in Michigan. Total annual maintenance accounts for running track were divided by both length of road and by total mileage of running track; the latter figure includes multiple tracks and sidings which require less maintenance per unit. These two figures are quite similar for the two example companies. The Norfolk and Western Railroad and the Chesapeake and Ohio Railroad spent \$4,249 and \$4,254, respectively, per mile of roadway for maintenance of running track. Equivalently, the two railroads spent \$3,115 and \$3,076, respectively, per mile of all running track. One may expect roadway maintenance cost per mile on lightly traveled branch lines to more closely resemble second tracks than mainlines.

Investigation of thirty-two abandonment applications has revealed the uniqueness of each case. While estimators of some liquidation price elements provide general understanding of avoidable opportunity costs, calculation of effective incentives require line-specific investigations. Agencies designing line continuation incentives would find it wise to train rail line appraisers to calculate the value of liquidation price elements.

Liquidation price is compared to the present value of expected net future earnings attributable to a railroad link, which would be lost by abandonment. Annual net earnings is the difference between operating revenues and operating costs obtained by accounting procedures of the ICC. Relevant operating income includes the entire amount of revenue attributable to shipments originating and terminating on the branch line. This value is composed of on-line charges for origination and termination services and that part of total freight revenue apportioned to the owning company for line haul operations on off-branch lines. The revenue figure must be adjusted downward for any amount of income which will be retained for traffic diverted to other portions of the company's lines. To the degree that traffic is diverted to company lines, revenue losses are reduced, increasing the amount of incentive payment required to encourage maintenance of a roadway.

Relevant operating costs are calculated similarly. All costs to the company incurred by handling traffic to and from the line under study are to be included. Operating costs represent long run marginal costs. Costs associated with branch operations and costs incurred in off-branch line-haul operations are included. ICC accounting procedures suggest calculating off-branch operating expenses at one-half the value of off-branch operating revenues. Costs of handling traffic diverted to other portions of the company's lines are to be subtracted as unavoidable with the proposed abandonment.

The value of subsidy necessary to relieve market pressures has been calculated for twenty-one of the thirty-two abandonment cases selected. Estimates are based upon data provided in the questionnaires submitted by applicant railroads. Application of the salvage and maintenance cost estimators is not appropriate since these same cases served as the sample used to construct the estimators. Total operating revenue attributable to a line less attributable operating costs, including _ad valorem_ taxes, was compared to the sum of net salvage value, the portion of normal annual maintenance expenditure not related to traffic, expected rehabilitation expenses and joint rent losses. All values were converted to present values assuming an indefinite time horizon and an eight percent discount rate, the 1972 average railroad bond rate. The results appear in Table 9.

The range of annual subsidy per mile required to cover opportunity losses of maintaining roadway range from $905 to $7,107 with a median of $4,631. Calculations for the Chesapeake and Ohio Railroad underestimate subsidies required to continue operations by an amount equal to the salvage value of land.

Present value of net operating revenue was negative in twelve of the twenty-one cases. Operating deficits had to be added to liquidation prices. This signifies that railroads tend to seek abandonment not when opportunity losses begin to occur but when accounting losses appear. By the time railroads reach operating deficits, substantial economic losses are incurred. Whether railroads create such financial pictures by discouraging traffic or whether these conditions are the result of reduced demand is not a key issue. This argument has been allowed to cover the deeper issue for some time and has created a great deal of animosity between railroads, shippers, and public agencies. That railroads either feel compelled to display operating deficits or that railroads continue operations until operating deficits occur, reveals a tendency to overinvest in roadway for periods extending beyond financial health of individual lines. Exclusion of opportunity losses and high uncertainty surrounding abandonment approval may be reasons for not fine-tuning investments to maximize market opportunity.

The Power of Pricing Policy

Previous development of roadway investment-disinvestment criteria assumed no limitations on management determinations except for pricing policy. Prices were assumed exogenously fixed implying either perfectly

TABLE 9. Estimated Annual Subsidies Necessary to Maintain Twenty-One Rail Segments Under Abandonment Application, 1968-1972

Company	Length (Miles)	Total Subsidy U_o	U_o Per Mile	Annual Subsidy U_a	U_a Per Mile
C & O	14.00	158,376*	11,313*	12,670*	905*
C & O	9.00	519,955*	57,773*	41,596*	4,622*
C & O	24.64	1,475,992*	59,902*	118,079*	4,792*
C & O	12.46	737,061*	59,154*	58,965*	4,732*
C & O	7.13	358,622*	50,298*	28,690*	4,024*
C & O	2.47	191,045*	77,346*	15,284*	6,188*
C & O	15.03	737.094*	49,042*	58,068*	3,923*
C & O	7.24	152,339*	21,041*	12,187*	1,683*
C & O	0.47	41,754*	88,838*	3,340*	7,107*
C & O	8.82	287,592*	32,607*	23,007*	2,608*
C & O	11.64	274,616*	23,592*	21,969*	1,887*
PC	4.3	308,060	71,642	24,645	5,731
PC	37.45	2,168,101	57,893	173,448	4,631
PC	5.9	291.993	49,490	23,359	3,959
PC	2.9	181,282	62,511	14,503	5,001
PC	19.8	785,877	39,691	62,870	3,175
PC	201.9	12,786,653	63,332	1,022,932	5,066
PC	25.5	1,038,184	40,713	83,055	3,257
GTW	35.57	2,954,806	83,070	236,384	6,646
C & NW	35.1	2,800,696	79,792	224,056	6,383
Soo	30.54	1,388,612	45,469	111,089	3,637

*Excluding land sale value.

elastic derived demand for railroad transport or continued regulatory influence over the pricing function. Consequently, magnitude of branch line losses has been determined conditional upon a set of fixed prices corresponding to a set of multiple products. Relaxing the assumption of predetermined prices will allow market conditions to influence pricing policies designed to reach management objectives. This will complete the view of the market bound to railroad service supply.

Firm pricing policy is a statement of principles by which prices of offered goods and services will be determined. Firms seeking to maximize net revenue over time tend to establish an output level at which long run marginal cost equals demand price. Implementing Clemens' notion of firms as sellers of capacity rather than sellers of products, one may say profit maximizing firms tend to equate long run incremental cost associated with a last unit of capacity with the demand price of items expected to be produced by that capacity.

Two characteristics of railroad operations have caused other than marginal cost pricing policy to be considered. First, railroads presumably exhibit decreasing unit cost in production throughout the relevant output or capacity range, owing to the high proportion of non-variable costs relative to variable costs, over long periods. The truth of this notion was questioned earlier in this chapter. Continually decreasing long run average costs imply smaller long run marginal costs at any selected output or capacity level. Consequently, if the demand facing the firm exhibits an inverse relationship between price and quantity demanded, pricing at marginal cost will not generate revenue sufficient to cover total costs over time. In this instance marginal cost pricing generates a deficit. One alternative is to adopt a policy of marginal cost pricing and seek government subsidies to clear the deficit. This approach is beyond the market bound. A market alternative is adoption of an average cost pricing policy with which the firm would establish prices equal to unit cost of operating and amortizing company facilities, including normal profits. In comparison with marginal cost pricing, average cost pricing generates higher prices and discourages demand. However, average cost pricing allows the firm to cover its total costs and remain in business. This pricing policy is often attacked on the grounds that as long as demand, representing marginal value to consumers of additional units of output, lies above marginal cost, general welfare could be enhanced by applying sufficient additional resources in production to increase output. This argument is used to justify the public subsidy alternative.

Secondly, railroads are producers of a number of distinct products sold in distinct markets. Under certain conditions a firm serving several markets can discriminate in price between markets. Price discrimination is typically defined as the differential pricing of different units of a single product, where the price differences bear no direct relationship to cost of production. The central objective of discriminatory pricing policy is to capture a larger proportion of the demand price particular groups of consumers are willing and able to pay. The necessary conditions for workable price discrimination may be met in railroad service markets. First, markets are clearly separable by commodity and origin-destination. Secondly, railroad services are perfectly perishable and so specifically defined by commodity and location as to preclude arbitrage activity. The final necessary condition requires that the selling firm have some control over price in the markets served.

Railroads do not always enjoy such influence over price, but in some circumstances a degree of price control may be possible. This condition must be explicitly assessed in each situation. Existence of more than a single railroad in a community and relative abilities of transport production between modes determines a railroad firm's discretion with price.

One advantage of discriminatory pricing policy is the ability to generate an average revenue covering costs where a single price would never justify production. Imagine demand relationships for two separable markets which both lie wholly below average cost. No single price could justify long term production. However, with high prices in the market of more inelastic demand and lower prices in the market of more elastic demand, the potential exists for an average price on total output which exceeds average cost. Under this special circumstance, discriminatory pricing policy allows the firm to operate profitably at a positive level of output.

Discriminatory pricing policy may also be applied to multiple product firms. Pigou described three degrees of price discrimination.[21] The first and second degrees, perfect discrimination and discrimination in price between discrete output blocks, respectively, assume single product production and a single demand curve representing the various classes of clientele. Third degree discrimination presumes the division of customers into groups, each group having a unique continuous demand function.

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[21] F. M. Scherer, Industrial Market Structure and Economic Performance (Chicago: Rand McNally & Company, 1970), pp. 253-254.

Multiple product price discrimination is an extension of Pigou's third degree. Clemens redefines discrimination for multiple product firms.

> Price discrimination exists in essence wherever a firm, producing a series of products, however differentiated, under joint cost conditions, recovers varying ratios of such costs by charging what the traffic will bear for each product.[22]

In effect, Clemens adds a fourth necessary condition that products be created with common or joint costs of production. Railroads as multiple product producers fulfill this requirement. As durable assets are shared by product lines, either simultaneously or in successive periods, a firm incurs joint or common charges. Though these costs must be covered to maintain production, these costs cannot be allocated directly to particular product units. Nonallocable costs of durable resources may be recovered from any unit of sales, not necessarily in proportion to the contribution of the resource. This situation encourages firms to sell at higher prices in markets least sensitive to price and at lower prices in markets more sensitive to price.

> In the bargaining between shipper and carrier the joint item (supplementary expense) will fall more largely upon the shipper who is more anxious to ship, and he will be the one for whose commodity there is a more intense demand.[23]

There are two rules for pricing policy when multiple outputs are produced with transferable, durable resources and market demand relationships are independent. First, to maximize profits marginal revenue must

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[22]Eli W. Clemens, "Price Discrimination in Decreasing Cost Industries," American Economic Review, 32 (December, 1941), 794-802.

[23]Haney, "Joint Costs," pp. 235-236.

be equal in each market and equal to marginal cost of the last unit of output.[24] Secondly, a firm will enter markets with successively greater price elasticity of demand until demand price equals marginal cost. A profit maximizing firm producing one product would select an output level equating marginal cost and marginal revenue. When the firm perceives an opportunity to shift durable resources to produce for a second market with greater price elasticity of demand, production for the two markets will be balanced to equate marginal revenue in each. Output for the originally produced good is reduced and the price raised. This process continues until the demand price of the last market entered equals the marginal cost of production. Beyond this output level marginal cost lies above marginal revenue, not warranting production.

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[24]A profit maximizing firm producing n products will maximize $\Pi = \sum_i p_i x_i - C(X)$ where p_i and x_i are price and output of product i, $i = 1, \ldots, n$, and C(X) is the total cost function. Maximization requires setting first order conditions to zero

$$\frac{\delta \Pi}{\delta x_i} = p_i(1 + 1/\eta_i) - C'(X) = 0$$

or

$$p_i(1 + 1/\eta_i) = p_j(1 + 1/\eta_j) = C'(X) \qquad i \neq j$$

that is marginal revenue from each product is equal to that of every other product and to marginal cost. Second order conditions require

$$\frac{\delta^2 \Pi}{\delta x_i^2} = \frac{\delta p_i(1 + 1/\eta_i)}{\delta x_i} - C''(X) \leq 0$$

that is, marginal cost must cut marginal revenue from below.

The three pricing policies discussed, marginal cost, average cost, and discriminatory pricing, by no means exhaust the multitude of possibilities. These three alternatives do represent those most often discussed in dealing with railroad and utility rate structures. In principle, marginal cost pricing is preferred among economists to make the most efficient use of society's resources, given the interpersonal structure of utilities and distribution of income which together determine effective demand and derived demand for transport services. However, Vickrey represents the context which limits application of this pure principle.

> As a preface to a discussion of the role of marginal cost pricing, it is perhaps well to state explicitly that in common with any other theoretical principle the principle of marginal cost pricing is not in practice to be followed absolutely and at all events, but is a principle that is to be followed insofar as this is compatible with other desirable objectives, and from which deviations of greater or lesser magnitude are to be desired when conflicting objectives are considered.[25]

Imperfections noted by Vickrey include the time and cost involved in determination and publication of rates as well as the time and costs to consumers of services to intelligently respond to price changes. These factors preclude rapid gyrations in prices required for strict implementation of short run marginal cost pricing. Also Vickrey notes that where strict long run marginal cost pricing spells financial disaster for decreasing average cost firms, the need for revenue calls for alternative pricing policies.

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[25]William Vickrey, "Some Implications of Marginal Cost Pricing for Public Utilities," in Transport, ed. by Denys Munby (Baltimore: Penguin Books, Inc., 1968), p. 98.

Of the remaining two policies discussed, differential pricing appears to have the most support in the literature. Average cost pricing is viewed as a poor substitute for marginal cost pricing when designed to generate revenues to cover costs of production, for the policy fosters inefficient use of society's resources. Differential pricing, on the other hand, is viewed as a complement to marginal cost pricing which has the ability to generate greater revenues than will marginal cost prices and stimulate efficient investment and output levels. Baumol notes the complementary relationship of marginal cost and differential pricing policies

> The margin above incremental costs which maximizes [the contribution to overhead burden and thus to net income] depends upon the price sensitivity of demand, determined primarily by the alternatives available to shippers . . . . Thus, while incremental costs should not determine prices or rates, they set the lower boundary within which pricing decisions should be made.[26]

Differential pricing has been suggested both as a means to make production possible in decreasing cost firms and to stimulate efficient allocation of resources. While the former may be possible under certain conditions of derived demand, the efficiency characteristics of differential pricing must be examined very closely. Baumol says "differential pricing is consistent with the public interest in the economical utilization of resources."[27] Clemens concludes that multiple product price discrimination serves as a substitute for public subsidy of decreasing

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[26]William J. Baumol, et al., "The Role of Cost in the Minimum Pricing of Railroad Services," in Transport, ed. by Denys Munby (Baltimore: Penguin Books, Inc., 1968), p. 124.

[27]Ibid., p. 125.

cost firms.[28] Multiple product firms continue to invade new markets until marginal cost equals demand price, implying a socially optimal level of output. Clemens uses a geometric application of Pigou's second degree price discrimination to establish his thesis. Second degree discrimination requires a single continuous demand relationship with distinguishable blocks of output. Discrimination essentially always results in greater outputs, under these circumstances, than with a single product price. However, second degree discrimination does not represent multiple product production.

Third degree and multiple product price discrimination, which best represent railroad markets, are less certain in their implications for socially optimal output levels. In these situations while output in the marginal market increases, outputs in intra-marginal markets are reduced. Whether total output with multiple product price discrimination is greater, equal to, or less than total output with a single price policy is not readily apparent.

Joan Robinson has provided conditions under which total output may increase, decrease, or remain unchanged by moving from a single monopoly price to third degree price discrimination.[29] As new market opportunities arise, firms tend to enter or increase production for markets of greater elasticity and lower price. Simultaneously output will be reduced in the less elastic markets and prices raised. Assuming demand curves are convex to the origin, total output then will decrease, remain the same, or increase according as the more elastic demand curve is

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[28]Clemens, "Decreasing Cost Industries," p. 800.

[29]Joan Robinson, The Economics of Imperfect Competition (London: MacMillan & Co., Ltd., 1933), pp. 188-193.

of lesser, equal, or greater degree of convexity than that of the less elastic demand relationship. The case of two straight line demand curves is a special case of equal degrees of convexity for which differential product pricing implies no change in total firm output relative to a single price policy. Consequently, one cannot judge a priori whether differential pricing will stimulate a more optimum level of output than charging all consumers alike.

Scherer provides another argument that multiple product price discrimination does not necessarily lead firms to produce at levels of socially optimal output.[30] Scherer points to the fact that marginal cost equals demand price only in the last market served; in all other markets demand price lies above marginal cost. Consumers are willing to pay more than marginal cost for additional units of product which are not being produced. While resources may be used efficiently in production of outputs for the last market, insufficient resources are devoted to products for the markets of less elastic demand, in the efficiency sense.

Mrs. Robinson does conclude, however, that in cases where price discrimination is necessary to make production feasible, such discrimination does promote efficiency of resource use.

> It is clearly desirable that price discrimination should be permitted in such cases, for the average revenue of the monopolist cannot be greater than average utility to the consumers. If average revenue is greater than average cost, average utility will also be greater, and the investment will lead to a gain to society.[31]

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[30]Scherer, Market Structure, pp. 260-261.

[31]Robinson, Imperfect Competition, pp. 203-204.

Stigler rebuts this argument, in part, saying that discrimination does "not necessarily" provide gain to each consumer when required for output. His argument faults Mrs. Robinson's statement for being too particular in view, ignoring price effects on other industries.

> . . . The production of one commodity that is priced discriminatingly will often affect the prices of other commodities. If a railroad will haul coal for 1 cent per ton-mile and diamonds for $100 per ton-mile, the shipper of diamonds may be compelled to use the railroad because it has driven out of existence the former stagecoach industry that hauled both commodities for 5 cents per ton-mile.[32]

The substitution effects implied by low prices of railroad service in markets of price elastic demand have implications for long-run development of a full range of transportation facilities in an area. Substitution effects on railroad competitors may be particularly critical in areas which generate a marginal amount of total exchange with other regions.

The issue of effects of price discrimination on related industries may be treated in similar fashion to the problem of using consumers' surplus as a measurement technique. Price discrimination amounts to the capture by firms of some of the consumers' surplus evident under single price policies. Consumers' surplus can be validly used as a rough measurement tool only if interactions with all related markets can be monitored. This requires railroad service to have only a few, identifiable substitutes or complements. Conceptually, then, one can trace the impacts of price changes in one market on the prices and output levels of related markets. The technique described is similar to Bailey's model of output and price determination for various products of multiple

[32]George Stigler, The Theory of Price (New York: The MacMillan Co., 1952), pp. 218-219.

product firms.[33] Here two distinct markets are considered, one for railroad services and the other for a railroad substitute. Figure 1A represents the market for railroad services. Multiple demand curves are drawn conditional on different amounts of sales of the substitute good. Demand curves are successively lower as more units of the substitute product are produced and sold in the combined market, noted by the ascending order of numbers, noting related market outputs, corresponding to successively lower demand curves. Marginal revenue curves associated with each demand curve are drawn and marginal cost of production is assumed constant for simplicity. Figure 1B is drawn similarly for the market of products produced by the related industry. Demand curves in this market are successively lower for greater sales of railroad services. Figure 1C represents a combined market for competing products. Demand for railroad services for different fixed levels of competing products is represented by demand function $X_{2.1}$. Demand for competing services for different fixed levels of railroad services is represented by $X_{1.2}$. Where these two curves intersect a simultaneous equilibrium exists in the two competing markets. Returning to Figures 1A and 1B, one can determine equilibrium quantities and prices for each product.

Let the price of a particular railroad product decline leading to an increase in equilibrium quantity in that specific market. As output increases and is consumed, the market demand for the competing product is diminished. This is noted as a shift downward in the demand relationship of the competing industry, corresponding to higher railroad service

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[33]Martin J. Bailey, "Price and Output Determination by a Firm Selling Related Products," American Economic Review, 44 (March, 1954), 82-93.

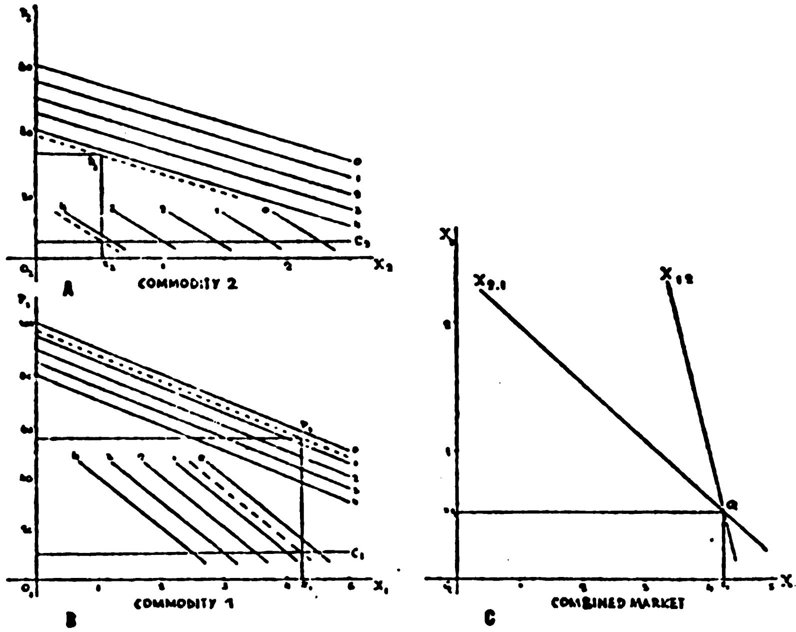

Figure 1.

sales. The competing industry of Figure 1B would equate marginal cost to marginal revenue at a lower level of output. If continued railroad capture of the transport market by means of price discrimination was to push the relevant demand curve for the competing industry below average cost, the competing industry may be forced out of business. Most assuredly if the demand curve of the competing industry was driven below average variable cost, the business would fail, illustrating Stigler's example.

Finally, price discrimination redistributes income. The purpose of price discrimination is to draw enhanced income away from shippers toward the railroad in order to make a branch line a viable operation. However, there is also a redistribution of income between shippers, relative to the instance of single monopoly price or single competitive price. Those shippers with inelastic derived demands for railroad transport will bear the largest portion of joint costs while those with more elastic demand will pay a relatively small share.

In summary, multiple product price discrimination may provide a market alternative to public subsidy to provide a condition of profitability which will encourage retention of rail lines. The characteristics of resource efficiency and distributional equity associated with this policy are unclear. The strength of this market mechanism depends upon answers to three basic questions in addition to fairness of distribution effects. First, does the railroad company have sufficient control over price of transport to discriminate in pricing? Two necessary conditions must be fulfilled to answer this question positively. One is that a margin must exist between current railroad rates and rates of next best alternative transport, a margin within which rail rates might vary without encouraging shippers to select another mode. Where the higher priced mode has superior service quality characteristics, the price margin must be discounted for the quality differential. The second necessary condition is that higher railroad rates not push shipping firms out of business, regardless of next best transport cost. This requires observation of the competitive environment of shipping firms, that is, assessing the shape of derived demand for transportation.

The second question to be answered about price discrimination is whether or not discrimination would generate sufficient added revenues to cover current losses, that is, is price discrimination sufficient to maintain operations. The answer to this question requires measurement of shipment volumes times price changes to arrive at a magnitude of potential revenue change.

A third question to be answered is whether price discrimination stifles transportation competitors or inhibits longer run resource adjustment of either transportation or rail user firms. Raising prices for transport to some firms without justification in cost and lowering prices to others may create perverse incentives tending to enhance use of resources in inefficient activities and stifle use of resources in more efficient enterprises.

The first two questions must be answered by firms forming price policy. The third involves systemic dynamics of external effects of firm decisions. A rudimentary procedure to test the potential of discriminatory pricing policy on branch lines makes use of actual freight rates of railroad and alternative modal services. Ability to influence prices requires that there exist a margin between the railroad rate and the rate of the next least costly alternative. Alternatives considered in Chapter VI are motor carrier, trailer-on-flat car (TOFC), and shipment to and from a nearby railhead with truck assembly and distribution. The margin may be discounted or inflated by a percentage to account for convenience and other service related values. Personal interviews with individual shippers and receivers may reveal the competitive environment controlling the ability of railroad users to accept higher freight rates. Some firms may not be able to stand increases in price to cover branch line deficits. Finally, an annual stream of revenue enhancement potentially to be gained by discriminatory pricing may be calculated by summing the possible contributions of railroad using firms on the subject line. The discounted net present value of discriminatory gains over the investment horizon may be added to the present value of net revenue from operations, resulting in a potential market value for the line. Potential market value may then be compared to line liquidation value to determine whether continued operation lies within the broadened market bound. This procedure will be applied to railroad lines in a two-county region of Michigan to test the power of pricing policy in expanding the market bound of supply.

The measure of potential revenue enhancement has application beyond price discrimination. This measure of willingness and ability to pay above current prices also serves to measure the magnitude of potential subsidy offered in private collective action by railroad users. This magnitude will be diminished in proportion to the degree of imperfection in product markets of railroad users, allowing passage of a portion of increased freight costs on to consumers. To the degree increased freight charges are passed on, consumers themselves would be willing to offer subsidy for line retention if suitable mechanisms exist to consummate the transaction. The present value of summed freight cost increases implied by railroad abandonment, becomes a component of potential market value of the line whether incidence of added freight charges is upon railroad users or consumers of their products.

Summary

Railroads have been described as multiple product firms where individual products are distinguished by commodity and location characteristics. The multiple product nature of railroad firms complicates long term capital adjustment behavior of managements. A competition is established between products, within firms, for use of scarce, durable resources. Where variable factors or market demand become constraining, excess capacity of durable inputs is not inconsistent with optimal resource use.

Assuming branch lines to be abandoned are of minimum capacity and that the optimal amount of movement equipment is not affected by a single branch line closure, a disinvestment rule was developed. Where discounted net present value of future operating revenues does not exceed liquidation value of the line, continued operation is possible only at a deficit equal to the difference. Due to the unique nature of each roadway segment, liquidation value, and magnitude of branch enterprise deficit, must be evaluated individually for each line.

Branch line deficits evaluated for twenty-one roadway segments under abandonment application revealed both the magnitude and the nature of deficits. Deficits ranged from $905 to $7,107 per mile suggesting considerable variation between lines. Branch line deficit evaluation also revealed that railroads tend to enter abandonment proceedings when operating losses can be reported, at which time economic losses may be substantial.

Two market mechanisms may exist through which added branch line revenue may be generated. Under certain market conditions, on-branch rate discrimination and collective user subsidies may potentially enhance line revenues to justify continued operation. The upper limit to this alternative is the value of the difference between costs of railroad and the next least costly shipping alternative.

This entire chapter has concentrated upon determinants of the market bound of railroad service supply. The concept of marginal revenue product, to which marginal opportunity factor costs are compared, has been assumed. As important to the investment decision as cost of production, is the likely level of future demand on a particular line segment. The next chapter considers the nature and determinants of prospective railroad service demand.

CHAPTER IV

THE MARKET BOUND -- DEMAND

Application of theory and empirical measurement of demand for transportation services has lagged far behind treatment of production and cost relationships. Not until the decade of the 1960's did a significant volume of this work appear. Some rather novel concepts have been developed to expand the theory of derived demand. Empirical work with freight transportation demand is new enough that the chief value of this activity has been development of a stock of statistical experience rather than a stock of valid estimates of relationship parameters. The results of treating railroad service demand here also must be viewed only as one more step in developing experience with transportation demand estimation. A review of previous approaches will precede construction of derived demand models used in this investigation. Both quality response and modal split models are developed for use in a traffic forecasting technique. Since survey data is spent designing estimators, parameters based upon the same available data are unreliable for traffic forecasting in this project. Valid parameter estimation requires data samples independent of the samples used in estimator development.

Two types of demand investigation predominate. One type emphasizes a particularist approach to identification and measurement of various determinants of demand, for each mode. Products of transportation have typically been recognized as possessing numerous characteristics other than price which affect demand. Multiple regression analysis has been the most common method for distinguishing the relative influence of each determinant. The second type of investigation views the entire transportation planning process with broader scope. Techniques of traffic forecasting dominate this field.

Meyer, et al., was one of the earliest to approach freight transport demand as a means to determine the feasible revenue gain with value-of-service pricing as opposed to marginal cost pricing.[1] Ability to charge prices above marginal cost is inversely related to elasticity of derived transport demand which, in turn, varies directly with elasticity of demand for the product being shipped and with the proportion of total commodity value composed of transport cost. Many bulky, low-value-per-unit commodities such as gravel and sand have price responsive markets and total value of materials is largely composed of transport costs. These products tend to have elastic transport demands. Transport costs used by Meyer, et al., include costs of storage and interest associated with transit time and minimum shipment volumes.

The earliest major attempt to empirically measure price elasticities of freight transportation demand was performed by Perle.[2] Short run own and cross price elasticities of demand for railroad and motor carrier services were measured with five years of annual time-series data. Perle recognizes the potential influence of non-price

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[1]John R. Meyer, et al., The Economics of Competition in the Transportation Industries (Cambridge: Harvard University Press, 1960), pp. 168-202.

[2]Eugene D. Perle, The Demand for Transportation: Regional and Commodity Studies in the United States (Chicago: The University of Chicago Press, 1964).

characteristics of movement and service, but only as longer term determinants of "secular change associated with intermodal competition and the fluctuations of market shares."[3] Measurement was made using a regression model with tons shipped as the dependent variable and rail and truck rates and regional and commodity group binary variables as independent variables. Poor statistical results led Perle to conclude that price behavior provides neither the sufficient nor the major answer to intercarrier competition. Perle offered two alternative explanations. Either non-price effects are active in the short run or transport demands are regionally unique. The latter explanation was selected and non-price effects neglected.

Subsequent contributions tend to suggest Perle was premature in placing non-price characteristics of transportation in an obscure role. Craig has developed a behavioral approach to modal selection using price and quality of service characteristics jointly.[4] Managers measure attributes of each mode by levels of anxiety and select the mode which best meets the objective of minimizing anxiety. Each modal characteristic is perceived differently under different environmental conditions and each manager applies anxiety weights according to his own predisposition toward each mode.

In Australia, Kolsen has developed a managerial utility model for modal choice similarly involving price-quality combinations.[5] Quality

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[3]Ibid., pp. 18-19.

[4]Thomas Craig, "A Behavioral Model of Modal Selection," Transportation Journal 12 (Spring, 1973), 24-28.

[5]H. M. Kolsen, The Economics and Control of Road-Rail Competition (Sydney: Sydney University Press, 1968), pp. 54-74.

of transport service is added at a cost and users are willing to pay higher prices for higher service quality. Assuming carrier and shipper firms maximize profits, carriers seek to obtain the highest possible price above marginal cost and shippers seek to pay the lowest possible price. The highest possible price one mode can receive for a particular level of a quality attribute is limited by the cost to another mode for providing the same service quality. Where modal competition exists, the lower bound of price is established at marginal cost of the highest cost producer. A very useful notion developed by this quasi-utility approach to derived demand is the implicit valuation by shippers of an array of service quality alternatives whether valuation is directly measurable or not.

> The quality characteristics of transport services are usually not taken sufficiently into consideration. Perhaps the main reason for this is the difficulty of giving them their correct "value," whereas costs and prices are more easily ascertained. . . . The user . . . has little difficulty in determining which combination of cost and quality is best for him.[6]

Though the ease of choice may be overstated, the notion of implied value weights, used by both Kolsen and Craig, suggests a revealed preference approach to transportation demand, even where dollar costs of consuming transport services are not readily identifiable.

Numerous studies of modal selection were undertaken in Europe during the latter half of the 1960's. Bayliss has summarized these investigations by four general approaches.[7] The market research approach

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[6] Ibid., p. 69.

[7] B. T. Bayliss, Demand for Freight Transport--Practical Results of Studies on Market Operation (Paris: European Conference of Ministers of Transport, 1973).

amounts to asking shippers of particular commodity types to rank a preselected list of factors affecting modal choice. No quantitative estimates of characteristic elasticities are attempted. Results of twelve such studies in different economic sectors and in different countries revealed that certainty of delivery time, speed, transport charges, and safety were consistently leading influences on modal selection. Similar studies seeking the major factors influencing major changes in modal split show that slowness and delays, loss and damage, and increased charges are the leading causes of shift from railroad to motor carriage. Relative freight charges alone appear to drive shippers to substitute rail for motor transport. Bayliss concludes that while market research reveals which quality characteristics are perceived to have value, the approach lacks ability to compare relative intensities of influence.[8] Consequently, one may hear shippers complain of service quality attributes while relative capabilities of alternative modes to satisfy shipper desires are insufficient to cause a change in shipping patterns.

A second approach is a forecasting technique to project traffic flows from broad-based movements in an economy. Estimates of the relationship between gross national product or total output of an industrial sector and demand for services by a particular mode are obtained by regression of transport used on an economic output indicator. The inverted output elasticity obtained assumes stability in relative sectoral output shares.

The consignment approach to modal choice relies upon actual observation of individual consignments. Information regarding the nature

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[8]Ibid., p. 23.

and characteristics of movement, charges, and service quality are collected for individual shipments. Probability models are estimated by regression techniques to show the probability of selecting a particular mode and the relative influence of the various modal attributes. Subjective evaluations of service qualities are used rather than actual figures since perception of quality by decision makers determines modal selection. Studies of this design in England have supported individual treatment of commodity types and inclusion of relative transport charges as a variable, for best results.[9]

Modal choice probability models have not given broad consideration to service quality characteristics; typically the influence of only physical movement characteristics is treated. The regression model developed for the Northeast Corridor Project regressed probability of shipment by a particular mode upon commodity value per ton, freight rate and a set of binary variables indicating shipment classification into consignment weight and movement distance categories.[10] Estimation problems did not permit use of results in forecasting. Problems may have arisen due to lack of conformity in the ranges of the dependent variable and the error term. The logit form of the dependent variable has been used in a Dutch study of commercial versus private motor carriage.[11] Only the influences of consignment weight and movement distance were considered. There appears need to expand modal choice probability models to consider the price and non-price determinants considered in conceptual approaches and revealed in market studies. This empirical technique bears the potential for estimating the

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[9] Ibid., pp. 32, 61.

[10] Ibid., p. 68.

[11] Ibid., p. 69.

quantitative influence of quality factors on demand for rail freight transportation.

Quandt and Baumol have expanded the econometric approach to predict demand for non-existent modes.[12] New modes are described by specifying particular bundles of travel characteristics which serve as new sets of independent variables in modal demand models. On the basis of estimated parameters of service quality for existing modes, predictions of quantity of service demanded of the new mode are estimated.

The Interstate Commerce Commission under order Ex Parte No. 270, "Investigation of Railroad Freight Rate Structure," is currently conducting a study using the consignment approach. Individual shipments by a selected number of firms will be surveyed to determine the influence of various factors affecting rail service demand. Tons shipped will be regressed on rail and truck rates, market price of goods moved, total annual firm production, transit time, transit time consistency measured as a percent of on-time arrivals plus or minus one day, and inventory turnover rate. The intent of the investigation is to determine whether regulated freight rates are consistent with strong multimodal competition.

The generalized approach to transportation planning treats transport demand as an element. Forecasts of traffic flows by individual network links guide the priority of investments. Meyer and Straszheim

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[12]Richard E. Quandt and William J. Baumol, "The Demand for Abstract Transport Modes: Theory and Measurement," Journal of Regional Science 6 (1966), 13-26.

have developed a procedural volume for transport demand forecasting.[13] First, the future spatial pattern of local economic activity is assessed by means of economic base studies. Estimates of expected activity are converted to physical estimates of traffic generated and terminated at different locations. Traffic originating and terminating at a particular location is distributed across regions adding the directional dimension to traffic. Modes are selected and routes assigned revealing the total estimated demand for transport service by link and by mode. Care must be taken to assure proper treatment of relative prices of commodities between regions. Existence of woodland does not insure a viable forestry industry. Trip generation must be representative of the relative value placed on products by local and external consumers. This procedure has been applied with a simulation technique in South America.[14]

Derived Demand for Transportation

Work previously done with transportation demand, just described, suggests a combination of techniques to determine the market bound. A generalized approach to demand forecasting is called for to determine the stream of traffic flow to be generated and terminated on particular line segments in question. To estimate demand potential on particular lines, projection of current traffic levels will not be sufficient. Service is understandably poor on some light density lines. To understand traffic potential at higher service levels, measurement of demand

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[13] John R. Meyer and Mahlon R. Straszheim, Pricing and Project Evaluation, Vol. 1: Techniques of Transport Planning (Washington, D.C.: The Brookings Institution, 1971), pp. 99-109, 165-181.

[14] Paul O. Roberts and David T. Kresge, "Simulation of Transport Policy Alternatives for Colombia," American Economic Review 58 (May, 1968), 341-359.

response to various levels of service quality is required. Such measurements will be particularly useful to local shipper organizations and governments seeking to determine a level of service to contract for in subsidy transactions.

Freight transportation is not typically desired as an item of final consumption. Rather, freight transportation is an intermediate input to production for which value is derived from the demand for final products at specific locations. As evidenced by research previously cited, each product of transportation is a unique bundle of many characteristics. These characteristics may be built into the model of derived demand for railroad services similarly to the manner in which price is conventionally treated.

For any firm g producing commodity i, assume a short run production function exists, describing maximum output quantities technologically feasible with various input combinations, of the general form

$$y_{ig} = f(x_h, x_r, x_m \mid x_p)$$

where

y_{ig} = quantity of output i produced by firm g,

x_h = quantity of a composite variable plant input, X_h,

x_r = quantity of railroad transport service, X_r,

x_m = quantity of motor transport service, X_m, and

x_p = quantity of a composite durable plant input, X_p.

Quantities of individual variable plant inputs composing the composite variable plant input, x_h, are assumed to be the optimum mix of resources used in the physical transformation process, given input prices and fixed plant resources, x_p. This amounts to assuming the marginal product per dollar of each input used at the plant site is equal to that for every other input used. Transportation inputs, X_r and X_m, inject time and place utilities into goods and services produced by the firm.

A profit maximizing firm will maximize

$$\Pi = p_i \, f(x_h, x_r, x_m \mid x_p) - r_h \, x_h - r_r \, x_r - r_m \, x_m$$

where p_i is product price and r_h, r_r and r_m are effective factor prices. Assuming a competitive product market and factor markets which are either competitive or regulated to provide constant prices, solution of necessary maximizing conditions for the three unknown quantities of inputs provides definition of unique derived demand functions for variable plant and transportation input flows,

$$x_h = d_h(p_i, r_h, r_r, r_m)$$

$$x_r = d_r(p_i, r_h, r_r, r_m)$$

$$x_m = d_m(p_i, r_h, r_r, r_m).$$

Quantity demanded of each input is dependent upon output price and the prices of all inputs. A sufficient condition for profit maximization is that the profit function be rising at a diminishing rate, that is, be concave downward, which requires

$$D = p_i^3 \begin{vmatrix} f_{hh} & f_{hr} & f_{hm} \\ f_{rh} & f_{rr} & f_{rm} \\ f_{mh} & f_{mr} & f_{mm} \end{vmatrix} < 0 \; .$$

Effective transportation prices, r_r and r_m, include more than published transport rates. Effective prices are total costs incurred by consumers of transport products due to use. Examples of these added costs are inventory and storage costs associated with goods in transit, cost of holding safety stocks as insurance against unreliable service, uninsured costs of damage, and many others. Effective transport price may be looked upon as the published rate r_p plus the costs associated with a vector of n service quality characteristics, r_q. Thus,

$$r_r = r_{rp} + r_{rq}(q_{r1}, \ . \ . \ . \ , q_{rn})$$

$$r_m = r_{mp} + r_{mq}(q_{m1}, \ . \ . \ . \ , q_{mn}).$$

The derived demands for transport services can now be represented as quality-price demand relationships,

$$x_r = d_r[p_i, r_h, r_{rp}, r_{rq}(q_{r1}, \ . \ . \ . \ , q_{rn}), r_{mp}, r_{mq}(q_{m1}, \ . \ . \ . \ , q_{mn})]$$

$$x_m = d_m[p_i, r_h, r_{rp}, r_{rq}(q_{r1}, \ . \ . \ . \ , q_{rn}), r_{mp}, r_{mq}(q_{m1}, \ . \ . \ . \ , q_{mn})].$$

One can estimate the demand for rail and motor freight service with product price, plant factor price, and effective transport rates.

The partial, derived, quality-price demand relationship may be pictured geometrically as in Figure 2 with quantity of transportation service of one mode on the horizontal axis and effective price on the vertical axis. The horizontal ray r_pP represents the level of published freight rates which are at any moment fixed by regulation for all quantities of service output. With zero consumption costs of using transport of the subject mode, that is, with "perfect" service characteristics, quantity of service OQ will be demanded. However, as service worsens

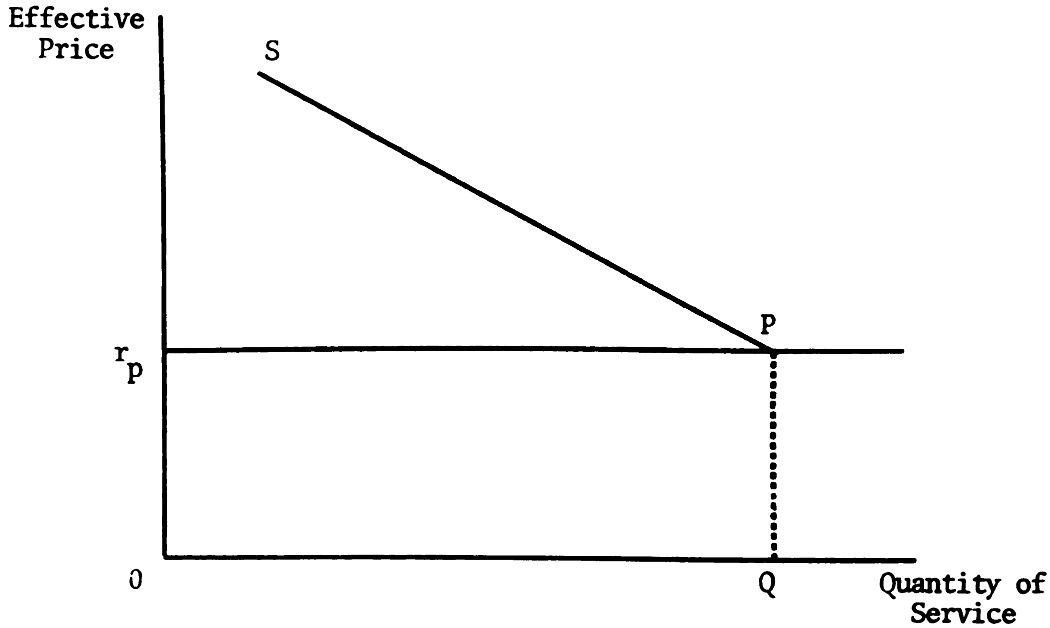

Figure 2.

in the perception of demanders, cost of consuming the service rises increasing effective transport price. Quantity demanded recedes along demand curve PS. Events which would tend to shift this demand curve are changes in relative service quality or price of other modes, technological change in the subject mode, or an autonomous change in preferences by transportation users, such as a growing acceptance of poorer and poorer quality as a fact of life.

To analyze the influence of a change in effective price of railroad service upon quantity of railroad service demanded, solve for change of quantity demanded, dx_r, by Cramer's rule,

$$dx_r = \frac{1}{D} \left[-p_i^2 (-f_h \, dp_i + dr_h) \begin{vmatrix} f_{rh} & f_{rm} \\ f_{mh} & f_{mm} \end{vmatrix} \right.$$

$$+p_i^2 (-f_r \, dp_i + dr_r) \begin{vmatrix} f_{hh} & f_{hm} \\ f_{mh} & f_{mm} \end{vmatrix}$$

$$\left. -p_i^2 (-f_m \, dp_i + dr_m) \begin{vmatrix} f_{hh} & f_{hm} \\ f_{rh} & f_{rm} \end{vmatrix} \right] .$$

Assuming $dp_i = dr_h = dr_m = 0$, the effect of a change in effective rail transport price upon quantity demanded of rail service may be isolated as

$$\frac{\delta x_r}{\delta r_r} = \frac{p_i^2}{D} \begin{vmatrix} f_{hh} & f_{hm} \\ f_{mh} & f_{mm} \end{vmatrix} = \frac{p_i^2}{D} (f_{hh} \, f_{mm} - 2f_{hm})$$

where D is negative representing the rate of change in slope of the three dimensional isoquant. The terms f_{hh} and f_{mm} are expected to be negative since rational production requires marginal productivities f_h and f_m to be less than average productivities and marginal productivities are declining when below average productivities. Consequently, to observe an own price effect which is negative the following condition must hold,

$$f_{hh} \, f_{mm} > 2f_{hm}.$$

If motor transport service and variable plant inputs are substitutes, added truck service inputs would force marginal productivity of the plant inputs down and $f_{hm} < 0$, easily fulfilling the condition for negatively sloped rail transport demand. If motor transport and plant inputs are complementary, which is intuitively more appealing, $f_{hm} > 0$ and the condition for a negative own price effect for rail transport services is sensitive to the relative magnitudes of the terms in the condition. If variable plant inputs and transportation services are being used near their extensive margins, rate of decline in marginal productivities may be slight relative to the degree of complementarity of truck and plant inputs. In this case, rail service could be an extremely inferior factor with an upwardly sloped partial demand function.

Assumption of independence of variable plant and transport inputs, $f_{hm} = 0$, results in a negative own price effect for railroad service without question.

$$\frac{\delta x_r}{\delta r_r} = \frac{p_i^2 \, f_{hh} \, f_{mm}}{D} < 0.$$

Assuming rational producer behavior f_{hh}, $f_{mm} < 0$ and $D < 0$, resulting in a negative own price effect.

Effects upon rail transport demand of a change in effective price of trucking may be isolated in similar fashion. Allowing $dp_i = dr_h = dr_r = 0$ and using the definition of dx_r resulting from use of Cramer's rule on total differentials of necessary conditions for profit maximization,

$$\frac{\delta x_r}{\delta r_m} = \frac{-p_i^2}{D} \begin{vmatrix} f_{hh} & f_{hm} \\ f_{rh} & f_{rm} \end{vmatrix} = \frac{p_i^2}{D} (f_{hm}\, f_{rh} - f_{hh}\, f_{rm}) \; .$$

A positive cross price effect reflecting increased railroad demand as truck prices rise requires that

$$f_{hh}\, f_{rm} > f_{hm}\, f_{rh} \; .$$

If the marginal productivities of plant inputs increase with addition of either transportation input $f_{hm}, f_{rh} > 0$. If truck and railroad inputs substitute for one another in production, $f_{rm} < 0$. Under these conditions one expects quantities of railroad service demanded and effective price of trucking to move in the same direction if the rate of decline in marginal productivity of variable plant inputs times the degree of substitutability of rail for truck service is greater than the product of the rates of increase in marginal productivities of variable plant inputs as additional units of each transport input are used.

For rail service demand and effective motor carrier service price to move in the same direction and have complementarity of truck and rail modes, $f_{rm} > 0$, one and only one of the modal transport inputs would have to cause a decline in marginal productivity of variable plant inputs with larger quantities of the transport input and still satisfy the condition

$$f_{hh}\, f_{rm} > f_{hm}\, f_{rh} \; .$$

Assuming variable plant and transport inputs are independent in production processes

$$\frac{\delta x_r}{\delta r_m} = \frac{-p_i^2 f_{hh} f_{rm}}{D} .$$

Under this independence assumption and the assumption of rational producer behavior, implying $f_{hh} < 0$ and $D < 0$, cross-price effects are positive or negative as truck and railroad services are substitutes or complements, respectively.

One final task is to isolate the effect of an incremental change in a single quality of service variable upon quantity of rail service demanded. Recall that effective railroad transport price is

$$r_r = r_{rp} + r_{rq}(q_{r1}, \ . \ . \ . \ , q_{rn}).$$

Assume a change in level of railroad quality characteristic $q_{r\ell}$ of magnitude $dq_{r\ell}$ such that

$$dr_r = \frac{\delta r_r}{\delta q_{r\ell}} dq_{r\ell} .$$

Holding published rail rate, levels of other railroad quality characteristics, effective motor carrier price, plant input prices and product price constant, total change in quantity of railroad service demanded in consequence to the quality change becomes

$$\frac{\delta x_r}{\delta r_r} dr_r = \frac{\delta x_r}{\delta r_r} \frac{\delta r_r}{\delta q_{r\ell}} dq_{r\ell} .$$

For a unit change in level of the service quality component, $dq_{r\ell} = 1$, quantity of railroad service demanded changes by a magnitude equal to

$$\frac{\delta x_r}{\delta q_{r\ell}} = \frac{\delta x_r}{\delta r_r} \frac{\delta r_r}{\delta q_{r\ell}} .$$

This theoretical result suggests empirical measurement of quality-demand response coefficients by regression of observed quantities of service demanded upon levels of service quality in their own natural units.

Effects of changes in motor carrier service quality upon railroad demand may be isolated similarly. Demand for railroad services is dependent upon effective motor carrier price

$$r_m = r_{mp} + r_{mq}(q_{m1}, \ . \ . \ . \ , q_{mn}).$$

Assume a change in a single motor service quality characteristic, $q_{m\ell}$, of magnitude $dq_{m\ell}$, such that

$$dr_m = \frac{\delta r_m}{\delta q_{m\ell}} \ dq_{m\ell} \ .$$

Holding effective rail rate, published motor carrier price, other motor service quality characteristics, plant input prices and product price constant, total change in quantity of railroad service demanded in response to the quality change becomes

$$\frac{\delta x_r}{\delta r_m} dr_m = \frac{\delta x_r}{\delta r_m} \ \frac{\delta r_m}{\delta q_{m\ell}} \ dq_{m\ell} \ .$$

For a unit change in characteristic $q_{m\ell}$, quantity of railroad service demanded changes by an amount equal to

$$\frac{\delta x_r}{\delta q_{m\ell}} = \frac{\delta x_r}{\delta r_m} \ \frac{\delta r_m}{\delta q_{m\ell}} \ .$$

Regression of railroad demand upon motor carrier quality characteristics, again, appears a useful method for estimating quality response coefficients of railroad demand.

Empirical Demand Models

Excepting the work of Perle, empirical transportation demand measurement has been predominantly oriented toward passenger travel. A large portion of empirical work has theoretical foundation in Lancaster's consumer technology theory which presumes consumer maximization of utility functions dependent upon attributes inherent in goods.[15] A similar approach has been adopted here in that producers are assumed to select modes on the basis of both price and non-price attributes rather than for the modes themselves.

Direct estimation of derived demand functions for freight service would require quantitative measures of attributes associated with individual service outputs and costs of consumption accompanying these service levels. The latter category of information is difficult to quantify and increasingly so at finer levels of disaggregation. As Kolsen suggests, paucity of measurable prices does not inhibit market transactions in freight service. Empirical models must be formulated which require quantitative information only for quantities of transportation demanded and levels of service quality attributes.

Previous theoretical developments revealed that the impact of a unit change in a service quality attribute upon quantity of service demanded operates through the effective price of that service. Determination of the relationship between quantities demanded of modal services and levels of service quality attributes indirectly reveal shipper valuation of transportation performance. Individual coefficients of such

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[15]Kelvin J. Lancaster, "A New Approach to Consumer Theory," Journal of Political Economy 84 (1966), 132-157.

relationships show demand responsiveness to variations in performance characteristics.

Two types of demand relationships are estimated for use in answering different questions. Quality response demand functions relate changes in rail and motor quality of service attributes to quantity of service demanded, after adjustment for individual firm and shipment characteristics. These estimates are useful for railroad companies seeking optimum service levels and by non-railroad investors for determination of terms of trade in rail service contracting. Secondly, modal choice probability functions relate quality of service to the probability that a randomly selected firm would use services of a particular mode. Modal selection probability results may be used directly in traffic forecasting to determine proportions of future traffic generations which will move by particular modes, under particular service quality conditions.

The estimation procedure used is similar to the econometric method developed by Griliches to measure hedonic price indices for automobiles, with specific treatment of quality attributes.[16] In Griliches' study, percent changes in price of automobiles were related to various quality variables in a semilogarithmic regression. The method used here is similar and directly consistent with theoretical results developed previously. Quantity of railroad service demand and modal split, within a

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[16]Zvi Griliches, "Hedonic Price Indexes for Automobiles: An Econometric Analysis of Quality Change," Government Price Statistics, Hearings U.S. Congress, Joint Economic Committee, January 24, 1961 (Washington, D.C.: U.S. Government Printing Office, 1961), pp. 173-196, in Arnold Zellner ed., Readings in Economic Statistics and Econometrics (Boston: Little, Brown & Co., 1968), pp. 103-130.

shipper firm, are explained by motor and railroad quality attributes and by firm and shipment characteristics.

A cross-section sample of total annual inbound and outbound shipments was obtained for individual firms in each of several industries. Shipments within firms were separated by commodity class and by origin or destination. Quantitative measures of motor and rail carrier service quality characteristics were also obtained for each individual firm. Average final product prices and average variable plant input prices were considered constant across firms during the single sample year, 1973. Normal seasonal price fluctuations do not affect annual total shipment volumes. Published motor and rail freight rates were also assumed constant under regulation, for all firms in the sample.

Under these realistic price constancy assumptions, variation in individual firm quantity of railroad service demanded depends only upon variation in modal service qualities. Across firms, shipping patterns are expected to vary by individual firm characteristics of firm size and ownership of transportation equipment. Larger firms are expected to ship larger volumes by all modes and potentially ship proportionally more by large volume carriers. Ownership of trucks could conceivably have offsetting effects on shipper behavior. Truck capacity may serve as an insured outlet allowing entrepreneurs to select cheaper modes of lesser reliability. Oppositely, use of trucks may erode volumes such that near total reliance must be placed on low volume carriers. Ownership or lease of railroad cars is expected to enhance use of rail service. Also affecting shipping patterns across firms is the average distance to markets favored by individual firms.

Quality response demand estimates for outbound shipments bear the general form

$$x_r = d_r(S, T, R, D, Sp_r, A_r, A_m, V_r, V_m, L_r, L_m, B)$$

where

x_r = quantity of rail service demanded (tons),

S = an indicator of firm size,[17]

T = 1 if the firm owns a truck; 0 if not,

R = 1 if the firm owns or leases a rail car; 0 if not,

D = average distance of rail shipments (miles),

Sp_r = average railroad speed (miles per day),

A_r = availability of railroad cars (average days of delivery delay),

A_m = availability of motor equipment (average days of delivery delay),

V_r = number of promotional visits by railroad firms,

V_m = number of promotional visits by trucking firms,

L_r = average value of damage in rail transit per $1,000 value,

L_m = average value of damage in truck transit per $1,000 value,

B = proportion of total shipments intended for railroad but diverted to trucks for lack of railroad cars.

Coefficients of linear regression for railroad service quality variables reveal isolated effects of unit changes in individual quality variables upon railroad transportation demand, via associated costs of consuming railroad services, that is,

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[17]For outbound grain shipments from elevators, grain storage capacity, in thousand bushel storage units, served as the size indicator. For all other commodity groups, size of firm is indicated by number of full-time employees.

$$\frac{\delta x_r}{\delta q_{r\ell}} = \frac{\delta x_r}{\delta r_r} \frac{\delta r_r}{\delta q_{r\ell}}$$

as derived earlier. Similarly, coefficients for motor carrier service quality variables record isolated effects of unit changes in individual truck service variables upon railroad transportation demand, via associated cross-price effects, that is

$$\frac{\delta x_r}{\delta q_{m\ell}} = \frac{\delta x_r}{\delta r_m} \frac{\delta r_m}{\delta q_{m\ell}} .$$

Units of transportation output are best defined as ton-miles. However, to hold average distance of shipment constant across firms, mileage distance is reserved as an independent variable. Total ton-miles is merely total tons shipped by a firm times average length of haul. To regress ton-miles on average length of haul would be superfluous and would give no more enlightening results than using tons shipped as the dependent variable.

Quality of service variables are measured in their own natural units. The implicit price associated with railroad speed is the value of interest charges on inventory in transit. The truck speed counterpart could not be included for most truck shipments were of less than one day. The railroad speed variable may be considered a ratio of railroad to truck speed where truck speed is a constant mileage range per day. The sign on the coefficient of this variable is expected to be positive, that is, as railroad speed increases, in-transit interest charges decline giving incentive for increased use of rail service, _ceteris paribus_.

Implicit consumption costs associated with delays in equipment delivery are the sum of storage costs and inventory charges for each day equipment is delayed. The coefficient of railroad equipment delay is expected to be negative since greater delays increase total unnecessary expenses, causing disincentive to rely on railroad service. The truck delay coefficient, on the other hand, is expected to be positive since higher expenses associated with motor carriers are likely to encourage use of railroad service, ceteris paribus.

Promotional contacts by phone, mail or in person serve to represent the degree of effort by transportation companies to please customers. Implicit values associated with these variables are numerous, including reduction in management requirements to establish rates and schedules of shipment. Coefficients on railroad and truck visits are expected to be positive and negative, respectively.

Damage in transit is costly in terms of poor customer service, money frozen in damage claims and uninsured losses. Coefficients on railroad and motor carrier damage in transit are expected to be negative and positive, respectively.

Proportion of total shipments intended for railroad shipment but diverted to motor carriers for lack of railroad cars is a proxy variable for reliability of outbound service. The value of service reliability lies in efficient use of shipper resources permitting ability to plan continuous flows of inputs and outputs through production facilities. Deviations from perfect reliability require reserve capacity in storage and flexibility in processing lines. The coefficient on the shipment diversion variable is expected to be negative as decreased reliability of railroad service discourages use of the railroad mode.

Modal selection probability is estimated with the same independent variables with a different dependent variable form,

$$\log \frac{P_r}{1 - P_r} = P_r(S, T, R, D, Sp_r, A_r, A_m, V_r, V_m, L_r, L_m, B)$$

where

P_r = proportion of total firm shipments moved by railroad.

A proportion, or probability, is limited to the range $0 \leq P_r \leq 1$. Direct estimation of firm, shipment and quality of service effects upon probability of selecting the rail mode would force estimation with a limited dependent variable. Classical linear regression models are potentially inappropriate when the regressand is bounded and the error term is not. Confidence intervals of estimated values may encompass nonsensical regions. To remedy this problem logit transformation creates a dependent variable with range $(-\infty,\infty)$. As P_r approaches unity, the logit form approaches the value ∞; as P_r approaches zero, the logit form approaches the value $-\infty$. The logit form and the error term thus have similar ranges.

When only railroad and motor carrier modes are considered the logit form becomes merely the logarithm of the ratio of rail to motor usage

$$\log \frac{P_r}{1 - P_r} = \log \frac{P_r}{(P_m + P_r) - P_r} = \log \frac{P_r}{P_m} \quad .$$

Interpretation of regression coefficients becomes the percent change in the ratio of railroad to motor shipments caused by unit changes in firm, shipment or quality of service characteristics. For a given observation of independent variables, absolute change of the probability ratio is obtained by multiplying the coefficient of regression by the observed probability ratio. From the new probability ratio formed by adding the change to the original ratio, a new modal split may be obtained.

Quality response and modal choice probability models for inbound shipments are similar, though abbreviated to account for less discretion by receivers over modal selection. The inbound quality response demand estimator appears in general form as

$$x_r = d_r(S,\ T,\ R,\ I,\ D,\ Sp_r,\ L_r,\ L_m)$$

where

I = number of days a firm could operate from inventories. Inventory flexibility is a characteristic of receiving firms. The greater is inventory potential, the less reliable transportation services must be to maintain efficient use of production line resources. The inbound modal choice probability model is similar,

$$\log \frac{P_r}{1 - P_r} = P_r(S,\ T,\ R,\ I,\ D,\ Sp_r,\ L_r,\ L_m).$$

Data and Model Quality

Some caution was taken in selecting quality variables, functional form and data base for estimation. Essential weaknesses of passenger transportation demand studies have been summarized by Quandt in four categories.[18] Three of these problematic categories were relevant for close scrutiny in this investigation. Two problems concern potentials for model specification error by omitting important variables and misspecifying functional form. Quandt also suggests need in passenger demand research for high quality data bases disaggregated to the household level, to test existing demand models. Data used in this investigation are disaggregated to firm level within commodity classes. Each of these three problems will be considered in turn.

Correctly specified econometric models bear full ideal conditions, consisting of observation matrices of full rank and independently and identically distributed errors (scalar covariance) of zero mean. For a model

$$y = Z\delta + u$$

where y is a nx1 vector of dependent variables, Z a nxk matrix of n observed values on k independent variables, δ a kx1 vector of constant parameters and u a nx1 vector of residuals, full ideal conditions imply

$$r(Z) = k$$

$$u \sim (0, \sigma^2 I).$$

Errors measure the dispersion of observed values of the dependent variable about their mean values $Z\delta$,

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[18]Richard E. Quandt, The Demand for Travel: Theory and Measurement (Lexington, Mass.: D. C. Heath & Co., 1970), p. 15.

$$u = y - Z\delta.$$

Incorrectly specified models will violate at least one of the ideal conditions. Violation of the full rank condition results in singularity of Z'Z yielding parameter estimation infeasible. Violation of the zero mean error condition leaves biased estimates. Violation of scalar covariance implies that observations are dependent and vary differentially about the mean. Incorrectly selecting variables and functional form result in biased estimates and nonscalar covariance.[19]

While rigorous econometric tests for specification error by omitted variables were not possible with available data, deliberate attempt was made to ensure inclusion of all behaviorally relevant quality of service characteristics. First, recall the leading influences of modal selection in twelve market research studies conducted in Europe and reported by Bayliss. Important determinants of modal selection revealed were speed, transport charges, safety of product and certainty of delivery time. Recall also that individual treatment of commodity groups gave best results in two English modal selection studies conducted with the consignment approach, also reported by Bayliss.

Results of previously performed informal market research in Michigan, by this investigator, were employed to ensure that quality

[19] James B. Ramsey, "Tests for Specification Errors in Classical Linear Least-squares Regression Analysis," Journal of the Royal Statistical Society Series B (Methodology) 31 (1969), 350-371.

of service variables selected were those most important in determining behavior of Michigan shippers and receivers. Twelve railroad user firms were non-randomly selected in the northern portion of Michigan's lower peninsula. Non-random selection permitted interviews with many of the area's largest railroad users. The manager or shipping manager of each firm was interviewed to see whether transit time, freight rates, damage and loss and service reliability affected modal selection. Open-ended questions also revealed consistent mention of delayed car delivery and attention by transportation representatives as important characteristics of transportation modes evaluated by users. Results of the informal survey are shown in Table 10. Though the survey did not cover the entire universe of this investigation, results are treated as prior knowledge in econometric analysis and all six characteristics mentioned consistently are added as quality of service variables in analysis.

Misspecification of functional form in model estimation also causes coefficient estimates to be biased with a non-diagonal variance-covariance matrix. A body of statistical information on quality-demand relationships in transportation is not available for review. Without guidance from either theory or previous statistical experience, relationship parameters cannot be estimated reliably, for the functional form of dependence of quantity demanded upon quality characteristics is unknown. Ramsey warns that if the true form of the function is unknown, then so too are the distributions of the estimators.[20] Lacking

[20]James B. Ramsey, "Models, Specification Error and Inference: A Discussion of Some Problems in Econometric Methodology," Bulletin of the Oxford University Institute of Economics and Statistics, 32 (1970), 301-318.

Table 10. Transportation Modal Characteristics Recognized and Evaluated by Twelve Michigan Shipping and Receiving Firms*

Characteristic	Frequency of Mention	Relative Frequency (12 Firms)
Transport Rate	8	0.67
Transit Speed	8	0.67
Reliability of Service	7	0.58
Damage and Loss	6	0.50
Equipment Delivery Delay	8	0.67
Attention by Transport Representatives	6	0.50

*Survey conducted during August, 1973.

knowledge of the distribution of estimators prohibits valid inference from estimates derived from sample data.

Two functional forms were subjected to four specification error tests developed by Ramsey, using data from early returns to the Michigan Freight Transportation Survey, from grain elevators.[21] These tests are RESET, RASET, KOMSET and BAMSET. The tests are complementary in that each has its strengths and weaknesses and the four tests together provide a more reliable analysis of each functional form than any single test.

The specification error tests approach their tasks by determining whether errors of test functional forms bear zero means and scalar covariances. Errors

$$u = y - Z\delta$$

[21]Ramsey, "Tests for Specification Errors."

cannot be tested directed for parameters δ are unobserved. Errors may be estimated, $\hat{u}$, by replacing true parameters δ with estimates $\hat{\delta}$, yielding

$$\hat{u} = y - Z\hat{\delta} = y - Z(Z'Z)^{-1}Z'y = My$$

$$My = M(Z\delta + u) = Mu.$$

The problem exists that estimated error terms are related not only to true errors, but also to the values of independent variables Z, through M.

$$E(\hat{u}\hat{u}') = E(Muu'M) = \sigma^2 M$$

revealing that observed regression residuals are not independently and identically distributed. If functional forms are to be tested for full ideal conditions by means of analyzing characteristics of regression errors, observed residuals must be modified to display scalar covariance.

Consequently, the four specification error tests rely upon residuals of best, linear, unbiased estimators with scalar covariance (BLUS residuals). Let the observed vector of residuals, $\hat{u}$, be linearly related to the vector of dependent variables, y, by a matrix A,

$$\hat{u} = A'y = A'Z - A'u.$$

Error in estimation then becomes

$$\hat{u} - u = A'Z - A'u - u.$$

For the observed residuals to be unbiased estimators of true errors

$$E(\hat{u} - u) = E(A'Z - A'u - u) = 0$$

requiring $A'Z = 0$, implying $\hat{u} = A'u$. Since the full vector of observed residuals, $\hat{u}$, harbors k linear dependencies with matrix Z, denoted by the vector of estimated parameter relationships, $\hat{\delta}$, matrix Z has a maximum rank of n-k.

A vector of n-k BLUS residuals, u^*, is formed by selecting n-k of the n observed residuals $\hat{u}$ which bear a linear relationship to their n-k corresponding true errors of

$$u^* = A'u.$$

The covariance of BLUS residuals is

$$E(u^*u^{*\prime}) = E(A'uu'A) = \sigma^2 A'A$$

requiring that $A'A = I$ to possess scalar covariance.

Minimizing the sum of squared estimation errors requires the condition that $(M - AA')J = 0$ where $M = I - X(X'X)^{-1}X'$ and J is a (n-k)xn matrix with a component (n-k)x(n-k) identity submatrix corresponding to the n-k selected residuals, with zeros elsewhere. For the (n-k)x(n-k) component matrix of M, M^*, corresponding to rows and columns associated with the n-k selected residuals, a matrix P may be formed where columns are composed of characteristic vectors of M^* satisfying

$$(M^* - \lambda I)p = 0$$

where λ are characteristic roots of M^*. A (n-k)x(n-k) diagonal matrix may be formed with diagonal elements equal to characteristic roots of M^*. The matrix A creating BLUS residuals can then be defined as

$$A = PD^{1/2}P'.$$

BLUS residuals may be generated from observed values of the dependent variable by substituting into the function

$$u^* = A'y.$$

In practice, the k rows and columns of the M matrix with smallest diagonal elements are deleted. This selection procedure amounts to removing the smallest of the residual weights, thereby limiting consideration to the largest deviations from the estimated mean. This builds in an element of conservatism when interpreting one functional form superior to another.

The null hypothesis of each specification error test is that the model form in question bears full ideal conditions. BLUS residuals are generated for each test model. For the true model

$$y = Z\delta + u$$

the null hypothesis appears as

$$r(Z) = k$$

$$u^* \sim (0, \sigma^2 I_{n-k}).$$

Under the alternative hypothesis an incorrect functional form is estimated, such as

$$y = X\beta + \varepsilon$$

where X is a nxk matrix of n observations on k independent variables, β a kx1 vector of constant parameters and ε a nx1 vector of residuals. Under an inappropriate functional form, other than full ideal conditions are expected. Assuming some non-linear functional relationship between corresponding elements of observation matrices Z and X, the distribution of BLUS residuals are expected to be

$$u^* \sim (A'Z\delta, \bar{\sigma}^2 I_{n-k})$$

where

$$E(u^* u^{*\prime}) = E(A'Z\delta\delta' ZA) = \bar{\sigma}^2 A'A = \bar{\sigma}^2 I_{n-k}.$$

The regression specification error test (RESET) directly evaluates the functional relationship between BLUS residuals and the regressors, with the null hypothesis that no such correspondence exists, that is, BLUS residuals have zero means. The alternative hypothesis is that BLUS residuals have means $A'Z\delta$, depending upon the specific form of misspecification. Again, the parameters δ are unknown, so estimates $\hat{y} = Z\hat{\delta}$ from the original regression are used. The RESET measures the relationship

$$u_i^* = \alpha_o + \alpha_1 q_{i1} + \alpha_2 q_{i2} + \alpha_3 q_{i3} + u_i \qquad i = 1, \ldots, n\text{-}k$$

where $q_{ij} = a_i'\hat{y}^{(j+1)}$ with a_i being the column of matrix A corresponding to residual u_i^*. If the F statistic of joint significance of the parameters α for this regression falls in the critical region, BLUS residuals have a mean significantly different from zero, that is, $u^* = A'Z\delta + u$, and the tested form

$$y = X\beta + \varepsilon$$

is not the true functional form. The RESET is the strongest test of the four in determining whether a functional form yields biased estimates.

The rank specification error test (RASET) is designed to distinguish whether squared residuals are distributed as central or non-central chi-square distributions. Under the null hypothesis of full ideal conditions u_i^{*2}/σ^2 are distributed as χ^2 with one degree of freedom. Under the alternative hypothesis of misspecification $u_i^{*2}/\bar{\sigma}^2$ are distributed as non-central χ^2 with one degree of freedom and parameter $\lambda_i = \delta' Z' a_i a_i' Z\delta/\bar{\sigma}^2$, where $\bar{\sigma}^2$ is the variance of BLUS residuals about their means $a_i' Z\delta$. Assuming $E(u^{*\prime}u^*) = \delta' Z' AA' Z\delta + \bar{\sigma}^2$ varies monotonically with $q_1 = A'y^{(2)}$, u_i^{*2} is expected to vary monotonically with q_{i1}. RASET tests the correlation of the rankings of u_i^{*2}, representing $\delta' Z' a_i a_i' Z\delta$, and q_{i1}, representing a function of the independent variables. If the rankings are similar, a dependence between errors and independent variables is revealed and the functional form is misspecified.

The n-k q_{i1} are ranked in order with corresponding u_i^* set adjacent. Rankings are assigned to each set of variables and Spearman's rank correlation coefficient, R_s, calculated

$$R_s = 1 - \frac{6}{(n-k)[(n-k)^2 - 1]} \sum_{i=1}^{n-k} (r_i - i)^2$$

where i is the integer rank of the ordered q_{i1} and r_i is the integer rank of the adjacent u_i^{*2}. The test statistic

$$t_r = \left[\frac{(n-k-2)R_s^2}{(1-R_s^2)}\right]^{1/2}$$

is distributed as Student's t with n-k-2 degrees of freedom, under the null hypothesis of full ideal conditions. If t_r falls in the critical region, evidence supports the alternative hypothesis of misspecification.

The KOMSET is a Kolmogorov test on the cumulative distribution function implied by the test form. The Kolmogorov statistic D_n is the greatest vertical difference between sample and hypothesized cumulative distribution functions at particular observed values of independent variables. With probability α of rejecting a functional form when it is the true form and n observed sample values, critical values d_α are obtained from published tables. If the critical upper or lower bounds of difference d_α are violated, the test form is rejected as not representing the true functional form.

Finally, BAMSET is a test for heteroskedasticity making use of a modified Bartlett's M test for unequal variances. Bartlett's M statistic is a likelihood function over the n-k observations corresponding to the n-k BLUS residuals. The statistic -2 log M is distributed as central chi-square with n-k-1 degrees of freedom. If the test statistic falls in the critical region of the chi-square distribution, the test form is rejected as not representing the true functional form.

Linear and semilogarithmic (or index) functional forms of inbound and outbound quality-demand response models and the logit form of the modal split model were evaluated. Of the first sixty returns from grain elevators to the Michigan Freight Transportation Survey, thirty-two provided sufficient information to test either inbound or oubound models. The sample sizes for inbound and outbound functional form tests are 25 and 18 observations, respectively.

Results of specification error tests using preliminary data for outbound grain shipments are displayed in Table 11. Significance of RESET and RASET test statistics is evidence that the linear functional form has biased error terms. The index functional form is seen to have

TABLE 11. Results of Specification Error Tests: Outbound Shipments

Test	Functional Form		Critical Value		Null Hypothesis	
	Linear	Index	5%	10%	Linear	Index
RESET $F_{3,7}$	5.2609	3.9424	4.35		Reject	Accept
RASET t_9	2.5973	1.0390	2.26	1.83	Reject	Accept
BAMSET χ^2_2	0.5534	1.1719	5.99	4.60	Accept	Accept
KOMSET D_n	0.2380	0.5344			Accept	Accept
R^2	0.9275	0.5618				
$F_{8,11}$	12.8000	1.2821	2.95			

unbiased errors by the same tests, such that the null hypothesis of full ideal conditions for errors is not rejected. With neither functional form does heteroskedasticity appear a problem, noting very small test statistics for BAMSET. In comparison, the linear form performs inferiorly to the index form in RESET and RASET.

The results of specification error tests are contrary to conventional model evaluation procedures. In the linear form 93 percent of variation in tons shipped is explained by the quality-demand model. The F test of joint significance of model elements is highly significant, suggesting the model as a whole explains well. The index functional form, on the other hand, evidencing consistent estimates by specification error tests, yields an R^2 of 0.56 and an insignificant F statistic, indicating the model has performed poorly.

Results of specification error tests and conventional tools of model validation are at odds. Since R^2 and F statistic evaluations do not distinguish between correctly and incorrectly specified functional forms, this evaluation may have provided an example of regression illusion in which a poorly specified model gives the investigator inflated confidence, which may lead to erroneous conclusions. Evidence suggests general superiority of the index form of the outbound quality-demand model. Results and interpretations will be presented for regressions under both functional forms, bearing in mind favor for the index form.

The equations for inbound shipments are less interesting. Both linear and index functional forms are supported as reasonable forms with which to estimate parameters, as seen in Table 12. Again the index form performs better than the linear form in the RESET and RASET tests. These tests have, thereby, done little to narrow the hypothesis

TABLE 12. Results of Specification Error Tests: Inbound Shipments

Test		Functional Form		Critical Value		Null Hypothesis	
		Linear	Index	5%	10%	Linear	Index
RESET	$F_{3,14}$	1.6931	0.1811	3.34		Accept	Accept
RASET	t_{16}	0.1611	0.2025	2.12	1.34	Accept	Accept
BAMSET	χ_2^2	0.3046	0.6639	5.99	4.60	Accept	Accept
KOMSET	D_n	0.1739	0.2435			Accept	Accept
R^2		0.4139	0.3052				
$F_{6,18}$		2.1185	1.3179	2.66			

space regarding functional form of quality-demand relationships for inbound shipments. At least some evidence is provided in support of further tests of these two functional forms using other data samples. The possibility always exists that more than one functional form will serve to represent a population.

Finally, the logit form of the modal selection probability model was subjected to specification error tests. Results appear in Table 13.

TABLE 13. Results of Specification Error Tests: Outbound Modal Selection Probability

Test	Logit Form	Critical Value		Null Hypothesis
		5%	10%	
RESET $F_{3,7}$	3.0993	4.35		Accept
RASET t_9	0.8199	2.26	1.83	Accept
BAMSET χ^2_2	3.2313	5.99	4.60	Accept
KOMSET D_n	0.3495			Accept
R^2	0.3085			
$F_{8,11}$	0.4461	2.95		

While R^2 and F statistics do not reveal significant explanatory power with preliminary data, specification error tests provide no evidence that the logit-linear functional form is inappropriate.

The final area of concern is the sample data used to estimate quality-demand and modal selection probability models. Data were accumulated from individual firms in various industry groups using a mail questionnaire survey. The questionnaire, distributed as the Michigan Freight Transportation Survey by the Michigan Department of State

Highways of Transportation, is available for review in Appendix A. The questionnaire contains three batteries of questions relating to inbound and outbound movement and quality of service characteristics and firm characteristics, for the year 1973. Movement and quality of service characteristics were collected for both motor and railroad modes.

Various industry groups were surveyed. For industry groups with many members, a random sample of firms was selected for participation from the most complete, available list of membership available. For industry groups including few individual firms, the entire population was asked to participate. Two mailings of the questionnaire instrument were performed to enhance the proportion of returns; the first was mailed May 1, the second June 15, 1974. Those returned for faulty address or lack of forwarding address were deleted from the sample.

Data are not of especially high quality. One objective of the Michigan Freight Transportation Survey was to obtain broad public participation in the transportation planning process. Completion of a vast number of questionnaire instruments was, consequently, unsupervised. Information received varies broadly in quantity and quality among industry groups. Some responses are clearly estimates; others contain exact figures from business records. Only data on inbound feed and fertilizer movements and outbound grain movements to and from Michigan grain elevators and farm stores were of sufficient quantity and quality to estimate quality-demand and modal selection probability models. For other industry groups surveyed, simple proportion means serve to provide estimates of modal split. Attempts to estimate transportation demand relationships in the manufacturing sector were wholly abandoned for lack of response to the data collection procedure.[22]

Regression Results

Unit, index and logit probability forms of the dependent variable were regressed on a linear function of firm, movement and quality characteristics of transportation by means of the ordinary least squares technique. Data of sufficient quantity and quality permitted complete analysis of only three commodity groups. Considered are outbound grain shipments and inbound feed and fertilizer movements originating and terminating at Michigan grain elevators and farm supply stores. The null hypothesis in each estimate is that all true population parameter values equal zero. Sample size was limited by data quality to small numbers of observations in each estimate. Small samples of microeconomic data typically harbor great variability under the best of circumstances. Two steps were taken to enhance the efficiency of estimators.

Regression on complete models incorporating all previously mentioned variables revealed active presence of multicollinearity problems. Several complete estimates displayed significant F statistics with no significant coefficients or constant term. Parameter estimates derived from estimators with multicollinearity are unbiased, but inefficient. To enhance efficiency of estimators, the data correlation matrix was reviewed to ascertain which pairs of variables represented close associations. Since two highly correlated variables may often be represented

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[22]Marc A. Johnson, The Michigan Freight Transportation Survey: An Investigation of Modal Split, Report to the Railroad Planning Section, Michigan Department of State Highways and Transportation, Lansing, Michigan, November, 1974 (Lansing, Michigan: Michigan Department of State Highways and Transportation, 1974).

by a single variable, estimators were formed with successive deletions of several highly correlated variables. Where parameter estimates do not change grossly and where efficiency measures improve, valid interpretation with deleted variables is possible. Where parameter estimates change substantially or efficiency measures deteriorate, variable deletion is not a valid procedure, for the variable may represent sufficiently independent influence upon the dependent variable to cause biasedness of other estimates when removed.

A second adjustment involved deletion of the variable most limiting data quantity. The purpose of this alteration is to enhance estimator efficiency by increasing sample size. Where parameter estimates are only marginally affected and where efficiency measures improve, the procedure produces valid estimates. Where parameter estimates change greatly upon removing a variable, the variable is important to the estimator and deletion produces inconsistent estimates.

Regression results of complete and adjusted estimators are provided for both index and linear forms of quality-demand models and the logit-linear form of the modal selection probability model. Recall that for outbound grain shipments, the index functional form was found to be superior to the linear functional form.

Outbound Grain Shipment: Index Form

Regression results of the quality-demand relationship for outbound grain movements from Michigan grain elevators using the index model form are shown in Table 14. The dependent variable is the logarithm of tons shipped by railroad. Individual regression coefficients are interpreted as the percent change in railroad service demanded due to unit

TABLE 14. Regression Results of the Quality-Demand Relationship in Index Functional Form: Outbound Grain Movements

Estimate	1	2	3	4	5	6	7
Constant	4.370290** (1.050975)	4.470605** (0.968879)	4.357191** (0.908728)	4.470163** (0.790074)	4.602171** (0.847778)	4.397941** (0.836268)	4.356420** (0.827850)
Railroad Distance	-0.000449 (0.001498)	-0.000836 (0.001222)	-0.000752 (0.001160)	-0.000765 (0.001092)	-0.001109 (0.001008)	-0.000665 (0.001075)	-0.000495 (0.001048)
Storage Capacity	-0.000002 (0.001003)	0.000501 (0.000268)	0.000531 (0.000252)	0.000513 (0.000232)	0.000501 (0.000565)	0.000544 (0.000259)	0.000592* (0.000251)
Own Truck	-0.312510 (0.694461)	-0.040744 (0.432808)	-0.110855 (0.399026)	-0.116519 (0.375650)	-0.055512 (0.271287)	0.055284 (0.296289)	0.031143 (0.292485)
Lease Car	-0.055693 (0.572050)	0.035669 (0.510806)	0.175292 (0.437972)	0.212477 (0.398141)	0.448088 (0.331761)	0.279526 (0.368867)	0.120834 (0.317305)
Percent Divert	-0.011850 (0.020222)	-0.015194 (0.017990)	-0.009621 (0.014887)	-0.008610 (0.013714)	0.003078 (0.001988)	-0.009838 (0.009483)	-0.013192 (0.008581)
Truck Delay	0.055727 (0.170227)	0.020084 (0.146297)	0.043513 (0.134989)		-0.053344 (0.081561)	-0.029969 (0.080636)	-0.019691 (0.079083)
Railroad Delay	-0.018112 (0.023410)	-0.025807 (0.017089)	-0.021129 (0.014647)	-0.022497 (0.013210)	-0.019675 (0.013151)	-0.020322 (0.012685)	-0.021650 (0.012486)
Truck Damage	0.070268 (0.192293)	0.105009 (0.169227)			-0.064201 (0.053322)	-0.046853 (0.054168)	
Railroad Damage	-0.013010 (0.018442)	-0.015732 (0.016591)	-0.005731 (0.003763)	-0.004823 (0.002348)	0.002816 (0.006540)	0.000681 (0.006651)	-0.004390 (0.003115)
Truck Visits	0.010952 (0.026202)	0.010425 (0.024548)	0.009564 (0.023408)	0.006373 (0.019987)	-0.017374 (0.015440)	0.002417 (0.020880)	0.006068 (0.020276)
Railroad Visits	0.078923 (0.150671)				0.011119 (0.062250)		
Railroad Speed	0.001201 (0.008970)	0.004163 (0.006528)	0.002301 (0.005538)	0.002103 (0.005186)			
Standard Error	0.493022	0.462249	0.441478	0.416018	0.518393	0.500441	0.496222
R^2	0.8109	0.8006	0.7878	0.7846	0.6108	0.6489	0.6302
F	1.7873	2.1897	2.5984	3.2383	2.1399	2.5877	2.8397
F Stat. Signif.	0.271	0.174	0.109	0.056	0.086	0.051	0.036
Sample	18	18	18	18	25	25	25

changes in movement, firm and quality of service variables. Estimator characteristics are summarized at the bottom of the table.

The estimator including all previously mentioned independent variables, equation 1, does not perform well. Influences of railroad promotional effort, truck damage and delays in motor freight equipment delivery were successively removed from analysis. Correlation coefficients for these highly related variables are reported in Table 15 for limited and expanded samples. Since the relationships between unreliable motor carriage disappear in larger samples, the truck delay variable was not removed with the larger sample.

TABLE 15: Correlation Coefficients for Highly Related Variables for Outbound Grain Shipments.

Relation	Sample Size	
	n = 18	n = 25
Railroad Visits and Storage Capacity	.944	.942
Truck Damage and Railroad Damage	.980	.864
Truck Delay and Truck Damage	.744	.395
Truck Delay and Railroad Damage	.730	.473

The variable limiting data quantity, railroad transit speed, was deleted to permit estimation with larger sample size. The R^2 delete statistic of this variable in the initial regression was 0.8103 where the model R^2 = 0.8109. Removal of railroad transit speed does not radically affect coefficient estimates, while increased sample size appears to give the model more of a chance to reveal its power.

For a given sample size, successive deletion of highly associated variables reduces standard errors of estimates slightly, though standard error is not reduced by enlarging sample size by the described procedure. Adjustments also erode the proportion of variation explained by independent variables. However, model adjustment does provide a basis for improving reliability of estimates in that the F statistic enlarges, becoming significant at the five percent confidence level in equation 7.

Though only size of firm appears a reliably significant determinant, the trend of significance level of Student's t-statistics of two quality variables is worth noting. As estimator 7 reveals, an increase (decrease) of 100,000 bushels in storage capacity results in a five percent increase (decrease) in quantity of railroad service demanded. Two quality of service variables, while not yielding statistically significant influence, may be worth further study with other data samples of greater quantity and quality. Levels of significance of Student's t-statistics for three variables are shown in Table 16 for the seven index form estimators.

Delay in delivery of railroad cars approaches the 10 percent significance level as the estimator is adjusted for multicollinearity and sample size. The coefficient on this variable remains stable throughout estimator adjustments, but standard error of the coefficient estimate continually declines. The coefficient may be interpreted as follows. Each day added to average delay in receiving railroad cars causes shippers to demand 2.2 percent less railroad service.

The influence of damage and loss associated with railroad shipment may be an important factor in quantity of railroad service demanded. Significance of this influence depends upon whether the variable of truck damage is included in the model. When truck damage is excluded from the estimator, railroad damage appears potentially important. A strong conclusion cannot be made to favor this result. Isolation of truck damage and railroad damage effects upon railroad demand will require a different specification of these variables.

TABLE 16. Levels of Significance of Student's t-Statistics for Coefficients of Three Potentially Important Rail Service Demand Determinants: Index Form of Outbound Grain Quality-Demand Function.

Estimate	1	2	3	4	5	6	7
Storage Capacity	.998	.111	.073	.058	.389	.054	.032*
Railroad Delay	.474	.182	.192	.127	.155	.131	.103
Railroad Damage	.512	.380	.172	.074	.673	.920	.179
Model F Statistic	.271	.174	.109	.056	.086	.051	.036
Sample Size	18	18	18	18	25	25	25

Outbound Grain Shipment: Linear Form

Results of the linear functional form estimators for outbound grain shipments are shown in Table 17. The dependent variable is the absolute number of tons shipped by railroad. This functional form was previously determined by specification error tests to yield biased estimates. Regression of the complete estimator results in a high multiple correlation coefficient and a significant F statistic at the five percent confidence level. Estimator adjustments for multicollinearity and sample size result in reduced standard deviation of estimates and larger, more significant F statistics. The multiple correlation coefficient is eroded little throughout estimator adjustment. The linear form suggests

TABLE 17. Regression Results of the Quality-Demand Relationship in Linear Functional Form: Outbound Grain Movements

Estimate	1	2	3	4	5	6	7
Constant	2920.6151 (14938.7961)	6067.4921 (15094.8265)	6299.9761 (13731.7998)	4603.9968 (11937.6781)	12878.1165 (10005.4341)	8663.4177 (9097.6491)	8424.2300 (8840.1666)
Railroad Distance	20.7386 (21.2870)	8.6079 (19.0330)	8.4350 (17.5214)	8.6381 (16.4986)	-12.2139 (11.9022)	-2.3615 (11.6981)	-1.3789 (11.1927)
Storage Capacity	15.0196 (14.2524)	30.8105** (4.1797)	30.7492** (3.8087)	31.0101** (3.5056)	37.7052** (6.6720)	31.0398** (2.8177)	31.3151** (2.6794)
Own Truck	-13938.2519 (9871.2223)	-5412.9101 (6743.0195)	-5269.1918 (6029.6894)	-5184.1683 (5675.9134)	-867.5292 (3201.7175)	-4250.7044 (3223.2912)	-4389.7684 (3123.2888)
Lease Car	-2906.2969 (8131.2552)	-40.2538 (7958.2007)	-326.4612 (6618.1980)	-884.7074 (6015.7330)	7839.1652 (3915.4338)	3444.3511 (4012.8501)	2530.1889 (3388.3249)
Percent Divert	-13.6934 (287.4333)	-118.5777 (280.2795)	-130.0021 (224.9603)	-145.1695 (207.2159)	43.9469 (23.4621)	-33.5500 (103.1643)	-52.8744 (91.6286)
Truck Delay	512.9107 (2419.6514)	-605.2044 (2279.2569)	-653.2308 (2039.8252)		-49.1356 (962.5789)	165.6620 (877.2310)	224.8722 (844.4891)
Railroad Delay	0.5923 (332.7487)	-240.8010 (266.2357)	-250.3902 (221.3269)	-229.8540 (199.5979)	-201.2426 (155.2081)	-140.9693 (137.9978)	-148.6159 (133.3271)
Truck Damage	-1305.0931 (2733.3013)	-215.2541 (2636.5099)			-725.3095 (629.3069)	-269.8997 (589.2855)	
Railroad Damage	120.9996 (262.1440)	35.6193 (258.4792)	15.1198 (56.8581)	1.4763 (35.4782)	75.6299 (77.1880)	26.3393 (72.3572)	-2.8728 (33.2587)
Truck Visits	-56.7927 (372.4365)	-73.3229 (382.4522)	-71.5590 (353.7128)	-23.6440 (301.9965)	-203.8124 (182.2245)	-55.3957 (227.1497)	-34.3582 (216.5182)
Railroad Visits	2475.8178 (2141.6704)				-1087.1605 (734.6742)		
Railroad Speed	-72.7589 (127.4959)	20.1495 (101.7115)	23.9650 (83.6842)	26.9463 (78.3612)			
Standard Error	7007.9225	7201.6917	6671.1730	6285.8562	6118.0532	5444.2315	5298.8857
R^2	0.9586	0.9475	0.9475	0.9467	0.9119	0.9349	0.9339
F	9.6503*	9.8537**	12.6307**	15.7946**	14.1209**	20.1090**	23.5613**
F Stat. Signif.	0.011	0.005	0.001	0.0005	0.0005	0.0005	0.0005
Sample	18	18	18	18	25	25	25

that only firm size plays an important role in quantity of grain shipped. The coefficient on firm size remains stable throughout estimator adjustment. Estimator 7 may be interpreted that every change in storage capacity by 1,000 bushels of space is likely to produce 31.3 tons change in railroad service demanded, or slightly less than one-third of a covered hopper car.

Empirical measures of service quality influences upon quantity of railroad service demanded do not resemble the intensity with which these factors are mentioned in market research and ICC railroad abandonment hearings. Quantity of railroad service demanded by individual grain elevators for outbound grain movements is nearly exclusively determined by firm size.

Outbound Grain Shipment: Logit Form

Estimates of modal selection probability for outbound grain movements are shown in Table 18. The dependent variable is the logarithm of the ratio of tons shipped by railroad to tons shipped by motor carrier. Results are not anticipated to resemble those for quality-demand estimates.

The complete modal selection probability estimator, including all potentially influential variables mentioned, appears useful, despite inefficiency caused by multicollinearity. Nearly 98 percent of variation in the dependent variable is explained by the independent variables and the F statistic of joint significance of coefficients is highly significant. Of the highly correlated independent variables, only the truck damage variable appeared to have no influence upon modal selection. Deletion of the truck damage variable causes no major changes in

TABLE 18. Regression Results of the Modal Selection Probability Relationship: Outbound Grain Movements

Estimate	1	2
Constant	0.801779* (0.248907)	0.925106* (0.302231)
Railroad Distance	0.001167* (0.000355)	0.000974 (0.000428)
Storage Capacity	-0.001541** (0.000237)	-0.001401** (0.000285)
Own Truck	-0.518680* (0.164472)	-0.374042 (0.186498)
Lease Car	-0.151753 (0.135481)	-0.233516 (0.162122)
Percent Divert	-0.002490 (0.004789)	-0.008032 (0.004985)
Truck Delay	-0.179436* (0.040316)	-0.209778** (0.047011)
Railroad Delay	0.001841 (0.005544)	-0.004406 (0.005837)
Truck Damage	-0.095229 (0.045542)	
Railroad Damage	0.012670* (0.004368)	0.003792* (0.001282)
Truck Visits	-0.023181* (0.006205)	-0.022665* (0.007750)
Railroad Visits	0.227324** (0.035684)	0.201588** (0.041862)
Railroad Speed	-0.010704** (0.002124)	-0.008251** (0.002213)
Standard Error	0.116765	0.145935
R^2	0.9773	0.9575
F	17.9455**	12.2783**
F Stat. Signif.	0.003	0.003
Sample	18	18

coefficient estimates, though estimate error, R^2 and the F statistic worsen. Since the variable limiting data quantity appears significant, the element could not be removed to allow use of a larger sample size.

Equation 1 of Table 18 suggests that there exist numerous movement, firm and service quality characteristics which affect modal selection. Three movement and firm characteristics and five service quality characteristics appear to influence modal split. Estimator 1 suggests that for an increase in average distance to railroad markets of 100 miles, the proportion of rail to truck shipment increases by nearly 12 percent. This may be explained by a declining substitutability of truck for rail service for longer distance distribution patterns.

Firm size and ownership of trucks affect the proportion of modal service used. Larger firms tend to place greater reliance upon motor carriage than do smaller grain handlers. As storage capacity of an elevator increases by 10,000 bushels, the proportion of rail to truck shipment is only half that of firms not owning trucks. This result may imply scale economies in truck ownership which allow larger firms to command a truck fleet. Smaller firms, then, may be left to the mercy of railroad service. This result also may imply scale economies in management. Larger firms may emphasize maximization of throughput volume requiring use of trucks to enhance flexibility in use of storage capacity. Isolation of the behavior implied by these results will require further study of transportation users.

Quality of service characteristics influence modal split in ways not all of which are intuitively appealing. As the informal market study of Michigan shippers revealed, individual shipper firm contact by transportation companies is important in modal selection. One visit by a trucking firm will decrease the ratio of railroad to truck use by 2.3 percent holding other influences constant. One visit by a railroad firm will increase the ratio by nearly 23 percent, holding other variables constant. Promotional contacts by railroad firms are few and there may exist diminishing returns to more and more effort. However, at these low levels of effort, personalizing railroading may have high payoff from grain elevators.

Other quality of service results are less intuitively appealing. The more unreliable is delivery of trucking equipment or the faster is railroad service, the smaller is the relative amount of railroad service used. Too, the greater the incidence of damage and loss associated with railroad shipment, the greater is the proportional reliance upon railroad service. Each result is isolated from other influences. The relative preference for slower service may conceivably reflect use of railroad cars as storage containers for shipments of undetermined destination. A prevalence of selling grain while in transit may cause such a result. The sign on the coefficient would be expected to reverse itself at low levels of speed which may threaten product quality. Reasons for regression results for railroad transit damage and sluggish trucker response are unclear.

Inbound Fertilizer Shipment

Estimators of quality-demand and modal selection probability relationships for inbound shipments provide evidence that the importance of individual service quality factors varies between commodity types. Results for fertilizer deliveries are shown in Table 19. The first two equations display results of the index estimator form with the logarithm of railroad tons received as the dependent variable. Equations 3 and 4

TABLE 19. Regression Results of Quality-Demand and Modal Selection Probability Relationships: Inbound Fertilizer Movements

Dependent Variable	Index Form		Linear Form		Logit Form	
Estimate	1	2	3	4	5	6
Constant	2.133493** (0.679766)	2.169780** (0.322113)	-10250.0216 (36006.8790)	3830.7547 (12711.8002)	0.752477 (1.037642)	-0.061172 (0.550282)
Railroad Distance	-0.000770* (0.000292)	-0.000431 (0.000278)	0.4501 (15.4774)	2.3059 (10.9870)	-0.001093* (0.000446)	-0.000466 (0.000476)
Employ.	0.031672** (0.004725)	0.030506** (0.005071)	1874.4038** (250.2664)	1842.1435** (200.1306)	0.019046* (0.007212)	0.016878 (0.008663)
Own Truck	0.085182 (0.434177)	-0.204794 (0.283835)	132.6793 (22998.1459)	-7629.7256 (11201.2009)	-0.853754 (0.662758)	-0.602239 (0.484889)
Lease Car	-0.128189 (0.271365)	-0.105153 (0.267292)	14865.4232 (14374.0868)	6830.9891 (10548.3633)	0.012849 (0.414231)	0.187394 (0.456628)
Railroad Damage	0.003878 (0.005880)	0.003566 (0.005979)	-205.8694 (311.4447)	-231.1959 (235.9544)	0.017126 (0.008975)	0.010651 (0.010214)
Truck Damage	-0.000896 (0.007848)	-0.002584 (0.008238)	264.9380 (415.7200)	267.6567 (325.0849)	-0.011454 (0.011980)	-0.010792 (0.014073)
Railroad Speed	0.011912** (0.003890)	0.011340** (0.003983)	-146.4386 (206.0428)	-186.9197 (157.1713)	0.010109 (0.005938)	0.008459 (0.006804)
Inventory Days	0.018732 (0.008745)	0.012648 (0.008305)	-437.9309 (463.2158)	-475.1079 (327.7589)	0.015095 (0.013349)	0.011428 (0.014188)
Rate Ratio	-0.308322 (0.275883)		5838.6891 (14613.3750)		-0.830186 (0.421126)	
Standard Error	0.358695	0.406390	18999.8954	16037.7098	0.547537	0.694257
R^2	0.8904	0.7731	0.8727	0.8355	0.7035	0.3792
F	11.7387	10.2238	9.9048	15.2344	3.4279	1.8326
F Stat. Signif.	0.0005	0.0005	0.0005	0.0005	0.022	0.120
Sample	23	33	23	33	23	33

provide results of the linear estimator form. Specification error tests support only slight preference for the index form of the estimator.

Both index and linear estimator forms provide a high degree of joint significance among parameters. Nearly ninety percent of variation in dependent variables is explained by the empirical models. Adjustments to enhance estimator efficiency do not improve properties of the index estimator form and only slightly improve properties of the linear estimator.

Three pairs of variables are highly correlated. The railroad to truck ratio of freight rates and distance to railroad markets are inversely related with correlation coefficient $r = -0.733$. Freight rate ratio and railroad speed and distance to railroad markets have correlation coefficients of 0.800 and 0.832 in limited and adjusted sample sizes, respectively. Adjustment for multicollinearity by variable deletion is not feasible with the index estimator form, for highly associated variables reveal significant coefficients of relationships. Similar adjustment for the linear form provides only marginal improvements in estimator properties.

The index estimator form of quality-demand relationship for inbound fertilizer shipments suggests three important determinants of railroad use. First, distance of supply sources from final distribution centers affects tons of fertilizer shipped by railroad. Equation 1 reveals that every hundred miles added to the average distance of supply points reduces amount shipped by 7.7 percent. This result may be interpreted either as a phenomenon of transportation cost friction in interregional trade or evidence of more and more intervening opportunities as supply points become more distant.

Firm size, measured by number of full time employees, appears a highly significant determinant of the amount of fertilizer an individual firm will receive by rail carrier. An increase in plant size which is indexed by an increase of one full time employee is accompanied by an increase in fertilizer receipts of 3.2 percent.

The sole service quality variable which appears to influence inbound fertilizer shipments is railroad speed. Faster service stimulates increased railroad shipments. An increase in average daily speed by one mile results in a 1.2 percent increase in fertilizer shipments by railroad.

The estimator of linear form suggests that only firm size determines volume of fertilizer shipments by railroad. An increase in firm size requiring one additional full time employee is accompanied by an increase in nearly 1,900 tons, or nearly twenty hopper cars, of fertilizer receipts by railroad, holding other potential influences constant.

The logit-linear estimator of modal selection probability also shows quality of service variables to be ineffective determinants of modal split behavior. Results of modal selection probability estimation are provided in equations 5 and 6 of Table 19. Only the unadjusted estimator has properties which permit interpretation (equation 5). Only railroad distance to supply points and firm size affect the ratio of railroad to truck shipments of fertilizer.

Increases in distance between supply points and distribution centers of ten miles result in reductions of rail to truck ratio of fertilizer delivery by 1.1 percent. Recall that absolute quantity of fertilizer drawn from railroad markets declined with greater distance. Evidently intervening opportunities do exist for substitution of truck for railroad delivery. Truck delivery of fertilizer from ports on the Great Lakes provide these opportunities. Though unit costs of these deliveries are higher than for railroad deliveries over comparable distances, short distance truck shipments appear to compete effectively with very long distance railroad movements.

Larger firms ship proportionally more fertilizer by railroad than do smaller firms. An increase in firm size by one employee increases rail to road fertilizer delivery by 1.9 percent.

Inbound Feed Shipment

Results of railroad demand estimates for inbound feed shipments to Michigan elevators and farm stores are shown in Table 20. The index estimator form is shown in equations 1 and 2 and the linear form in equations 3 and 4. With both forms more than 95 percent of variation in the dependent variable is explained by firm, movement and quality characteristics.

There are two pairs of highly correlated variables. Truck damage and railroad damage have correlation coefficients of 0.865 and 0.864 for limited and adjusted sample sizes, respectively. Inefficiency caused by this association cannot be remedied, for both variables have significant regression coefficients. Railroad transit speed and railroad distance have correlation coefficients of 0.549 and 0.707 for limited and adjusted sample sizes, respectively. Railroad distance is deleted to improve estimator efficiency.

The variable limiting data quantity is the ratio of railroad to truck freight rates. Removing freight rate ratio information from the

TABLE 20. Regression Results of Quality-Demand and Modal Selection Probability Relationships: Inbound Feed Movements

Dependent Variable	Index Form		Linear Form		Logit Form		
Estimate	1	2	3	4	5	6	7
Constant	2.359494* (0.441611)	2.475405** (0.399858)	-405.2568 (744.4850)	357.1816 (507.8409)	-0.245093 (1.046549)	-0.188683 (0.631456)	-0.078819 (0.562514)
Railroad Distance	0.001132 (0.000568)		0.7516 (0.9574)		0.001461 (0.001346)	0.000397 (0.000915)	
Employ.	0.000077 (0.009512)	0.010154 (0.010581)	19.4023 (16.0364)	28.1439 (13.3263)	-0.037494 (0.022543)	-0.017743 (0.015624)	-0.016380 (0.014885)
Own Truck	0.793366 (0.281709)	0.326742 (0.333338)	795.4205 (474.9156)	492.3614 (311.7786)	1.648328 (0.667606)	0.886147 (0.526713)	0.794229 (0.468935)
Lease Car	0.370465 (0.242576)	-0.127565 (0.274343)	-62.3057 (408.9448)	-162.8048 (272.6984)	0.481488 (0.574868)	0.025901 (0.426250)	-0.041567 (0.385942)
Railroad Damage	0.015437* (0.003221)	0.012298* (0.004711)	29.1132* (5.4305)	31.2469** (4.4254)	0.007716 (0.007634)	0.004156 (0.006890)	0.003713 (0.006627)
Truck Damage	-0.050830* (0.011695)	-0.030340 (0.015403)	-58.7880 (19.7165)	-60.9383** (15.0504)	-0.046735 (0.027716)	-0.017361 (0.022858)	-0.015148 (0.021669)
Railroad Speed	-0.012056 (0.005289)	0.001659 (0.004371)	3.0535 (8.9159)	8.1243 (6.5775)	-0.023119 (0.012533)	-0.009655 (0.008698)	-0.007065 (0.006149)
Inventory Days	-0.014330* (0.003907)	-0.007370 (0.004996)	-12.4788 (6.5871)	-8.8274 (6.0234)	-0.034302* (0.009260)	-0.023980** (0.007226)	-0.023980** (0.007028)
Rate Ratio	0.245135 (0.244256)		310.8874 (411.7769)		0.400495 (0.578850)		
Railroad Rate				-10.0729 (12.9414)			
Truck Rate				-3.0602 (5.0544)			
Standard Error	0.215449	0.382164	363.2114	284.5390	0.510579	0.552793	0.537623
R^2	0.9537	0.5447	0.9658	0.9790	0.8962	0.5920	0.5866
F	6.8691	2.5636	9.4242	15.5658	2.8769	2.5396	3.0401
F Stat. Signif.	0.070	0.060	0.046	0.023	0.208	0.061	0.034
Sample	13	23	13	13	13	23	23

estimator results in increased standard errors for estimates and substantially reduced explanatory power. However, joint significance of the parameters improves with larger sample sizes.

The index estimator form does not show strong joint significance of the explanatory variables. Damage in transit by truck and rail modes and inventory stocks appear potentially important determinants of demand. The linear estimator form possesses superior properties of explanatory power and joint significance of parameters. Sample size adjustment with removal of freight rate information makes the linear estimator unusable. In transit damage by both modes again appears important in determining quantity of railroad feed shipments.

Modal selection probability estimators for inbound feed shipments are shown in Table 20, equations 5-7. Throughout adjustments for multicollinearity and sample size, estimators revealed that only inventory capacity affects the relative proportion of modal selection. Estimator 7 suggests that as ability to operate from inventories increases by one more day, the ratio of railroad to motor carrier use declines by 2.2 percent. Intuitively one might expect to observe firms with greatest inventory flexibility placing greater reliance upon slower, less reliable modes. The observed results may be interpreted in one of two ways. Most feed shipments arrive from a small number of origins in northern Indiana. Given that other influences are held constant, one may conclude that for feed shipment, trucking provides less reliable delivery service than do railroads.

Another explanation for the inverse relation between inventories and relative preference for railroad service is a short run, cyclical phenomenon. The year 1973 was characterized by rapidly rising feed prices and interest rates. The negative relationship may reveal an attempt by firms with large inventories to liquidate stocks to more closely manage inventory costs. The draw down of inventory stocks would require smaller inbound volumes which are more reasonably hauled by motor carriers. Evidence for such an explanation is not conclusive. Further study is warranted to explain the cause of the measured influence of inventory stocks upon modal split.

Summary

Fertilizer and feed are quite different commodities with respect to transportation. Fertilizer is a commodity chiefly purchased in bulk form for seasonal use. Consequently, speed is the quality characteristic of transportation which is important to meet narrow schedules of seasonal market demand. Fertilizer components are products of basic extraction activities. These commodities are of a bulky, low-value-per-unit nature. Transportation costs are a major element of total fertilizer value. As a result, distance to supply points is an important determinant of demand. Due to the system of distribution established in the fertilizer market, truck shipments of plant food from lake ports serve as intervening opportunities to long distance overland movements.

Feed, on the other hand, enters Michigan in bagged form for sale throughout the year. Supply points are located closeby in the midwestern region. Unlike bulk fertilizer, bagged animal feed is susceptible to damage in transit through breakage. Consequently, amount of damage associated with particular modes affects the quantity of service demanded of those modes.

Regression results support the conclusions of two British studies of modal selection, reported by Bayliss. Those investigations suggested that commodities should be given individual treatment and that modal freight rate ratio be included in regression analysis. Differences in results for inbound feed and fertilizer movements suggest that as supply and product market characteristics and physical characteristics of individual commodities differ, importance of various service quality factors also differs. The importance of including the freight rate ratio is shown in Tables 19 and 20. For nearly all inbound railroad demand estimators, deletion of the freight rate ratio variable increases standard errors of estimates and deteriorates explanatory power, despite larger sample sizes permitted. The ratio of freight rates did not show a significant influence on quantity of railroad service demanded or modal split, after other influences were considered. However, freight rate ratio appears an important element of the estimator, especially for prediction purposes.

Regression results reveal that the index form of quality-demand relationships isolates several important railroad service demand determinants, even with small samples of microeconomic data. Estimated parameters must be used with extreme caution. Data used in specification error tests of functional form were included in the samples used for estimation. Paucity of data prohibited separation of the data sets. Consequently, parameter estimates are derived from regression on equations with functional forms tested with a portion of the data used to make actual estimates. Further studies with new data are suggested to derive independent estimates using results of specification error tests as prior information.

Market research and testimony before ICC abandonment hearings have suggested that quality of service has a major impact upon quantity of railroad service demanded. Results of regression on quality-demand and modal selection probability models reveal that service quality may well affect railroad service demand, but not to the extent suggested. The difference between vocal complaint and action can be explained by the concept of economic action thresholds. Kolsen's shipper utility model approaches this type of explanation. While a shipper may be inconvenienced by relatively poor service of the railroad mode, operating costs associated with poor service quality may not exceed the difference between published railroad and motor carrier freight rates. Given a particular firm output level, the less costly transportation mode may decrease service quality until effective price of consuming services equals the effective price of the next least expensive mode. Only at this level of service deterioration will the shipper have reached an economic action threshold which causes a change in modes.

However, an increase in effective price of the least cost mode will tend to raise marginal costs of production to the shipper firm. To the extent that quality of service deterioration causes reductions in plant outputs in reaction to increased marginal production cost, quantity of railroad service demanded may decline slightly for each decrement in service quality.

Infancy of railroad service demand estimation has required spending available data on basic development of statistical experience with quality-demand and modal choice probability functions. Estimators do not bear qualities required for inclusion in a detailed traffic forecasting model. New, independent data samples would be required.

Empirical demonstration of branch line analysis, contained in Chapter VI, will rely on conventional trend projections for traffic forecasting. Further data base development will, in time, enable more sophisticated traffic forecasting procedures which consider contracted levels of service quality.

The market bound to provision of branch line service is nearly complete. Willingness and ability of individuals to pay for external effects associated with presence of a line are considered in the next chapter. Values external to consideration by railroad management may expand the market bound by means of private collective action. Other external values add to the market bound to establish the social bound to railroad branch line service provision.

CHAPTER V

THE SOCIAL BOUND

Governments of societies which offer citizens opportunity to make their own major decisions, serve as collective producers and market regulators to adjust market performance for external effects of private action or inaction. External effects are influences of one actor upon another for which account is not taken in decision processes. To the extent market adjustments can be made by compensatory agreements between individuals or between groups of individuals in collective action, the adjustments are an extension of the market bound. For economy of discussion, consideration of external effects has been reserved for development of the social bound.

The Regional Rail Reorganization Act of 1973 has provided states, communities and shipper groups an opportunity to subsidize local railroad operations. A chief objective of this research is to provide criteria and procedures with which state and local agencies may evaluate railroad branch line investment alternatives. Two questions arise. Do benefits of continued line operation exceed opportunity costs of provision? If so, who is to bear these costs? First, a criterion will be established by which to determine net benefits. Secondly, consideration will be given to who might bear the costs. The limits of market and public action will be distinquished. The social bound to production and investment encompasses both market recognized and external benefits and costs of actions.

Externality

External effects have been described as influences of one actor upon another for which account is not taken in decision processes. Buchanan and Stubblebine have developed definitions for various classifications of external effects which will serve to illuminate different kinds of interactions between railroad firms and members of local communities.[1] Definitions of the various types of external effects will be used to develop criteria for private collective and public action, and to take account of various special issues involving organization and transaction. Modifications of the Buchanan-Stubblebine definitions are necessary to isolate only those dependencies between objective functions which are not accounted for and to consider the current distribution of income.

Assume the existence of a local railroad line owned and operated by a railroad company for which management's objective function is

$$U^R = U^R (y_k) \qquad k = 1, \ldots, n$$

where y_k is the flow of railroad service produced on railroad link k. Assume also a single, local consumer of railroad service with objective function

$$U^C = U^C (x_i, y_1) \qquad i = 1, \ldots, m$$

where there are m activities X_i for which the consumer holds both positive value and the power of decision to control the level of these activities, and y_1 is the flow of railroad service on the particular link 1, serving the consumer's community. The consumer may be one of three

[1]James M. Buchanan and William Craig Stubblebine, "Externality," Economica 29 (November, 1962), 371-384.

persons. The consumer objective function may be that of a direct user of railroad services such as a retailer or consumer of products delivered by railroad, an employee of a firm with direct or indirect usage of railroad service, or a nostalgia buff who enjoys counting cars. Finally, the consumer may be one who perceives no immediate use of the railroad but desires to maintain the option to use railroad services in some future period, such as a prospective businessman. In fact, a single individual may represent all three of these persons simultaneously.

Inclusion of the railroad activity in both railroad and consumer value functions, establishes an interdependence between objective functions. To the extent the railroad does not consider the value of railroad service to consumers, this interdependency represents an external effect of railroad decision processes. Values expressed in the market demand function for railroad service are internalized in the process of price determination. Even for low priced portions of the demand function which are not serviced, the fact that that portion of the demand function was recognized and deliberately not serviced, represents internalization of the interdependence.

A marginal external economy is realized by the consumer when

$$\frac{\delta U^C}{\delta y_1} > 0$$

with no visible means of market articulation of this value. Small changes in railroad service enhance the consumer's worldly position. A marginal external diseconomy exists when

$$\frac{\delta U^C}{\delta y_1} < 0$$

and is ineffectively communicated to the railroad firm in terms of price. Incremental changes in service create a cost to the consumer.

Non-marginal externalities are those for which the consumer perceives no change in usefulness of small alterations in service, but major shifts in service do create an impression upon the consumer. A non-marginal economy exists when

$$\frac{\delta U^C}{\delta y_1} = 0 \text{ and } \int_0^{y_1} \frac{\delta U^C}{\delta y_1} \, dy_1 > 0$$

for some given level of all activities X_i controllable by the consumer. In this form, the definite integral evaluated from zero to the current output level y_1 implies the consumer gains nothing from minor changes in service level, but the consumer holds some positive value for the continued existence of railroad service. Other non-marginal external economies may be evaluated between any two levels of service which are considerably distinct, such as the difference between daily and once per week service levels. A non-marginal external diseconomy appears when

$$\frac{\delta U^C}{\delta y_1} = 0 \text{ and } \int_0^{y_1} \frac{\delta U^C}{\delta y_1} \, dy_1 < 0$$

for a given level of all other consumer activities. While minor changes in service have no perceptible effect on the consumer, mere existence of the railroad creates a disutility for the consumer. For non-marginal dependencies to be truly external effects of railroad operations, these effects must be poorly communicated to the railroad company via pricing signals.

Development of further definitions of externalities requires the notion of equilibrium output levels for the railroad firm. Assume the railroad has an exchange opportunity function

$$E^R = E^R (y_k) \qquad k = 1, \ldots, n$$

whereby resources involved in link activity y_k may be exchanged in the market place or between links. To maximize the railroad's objective function, U^R, marginal rate of substitution in production must equal marginal rate of substitution in exchange, for any activity y_k. Thus, a private equilibrium level of railroad service $\bar{y}_1$ produced on link 1 will satisfy the condition

$$\frac{\delta U^R/\delta y_1}{\delta U^R/\delta y_j} = \frac{\delta E^R/\delta y_1}{\delta E^R/\delta y_j}$$

where y_j is the level of production or exchange for a numeraire link j. The marginal rate of substitution in exchange represents the opportunity cost of resource use in actually producing railroad service on a particular link.

When the railroad company produces equilibrium service level, $\bar{y}_1$, a potentially relevant externality exists if the consumer desires some other level of service and railroad management does not know of this desire. Potentially relevant marginal economy and diseconomy exist when

$$\left.\frac{\delta U^C}{\delta y_1}\right|_{y_1 = \bar{y}_1} > 0 \text{ and } \left.\frac{\delta U^C}{\delta y_1}\right|_{y_1 = \bar{y}_1} < 0$$

respectively. That is, given service level $\bar{y}_1$, if the marginal gain (loss) to the consumer of incremental service units is positive, the consumer may potentially seek to encourage the railroad company to increase (decrease) service levels. Objective function dependencies are marginally irrelevant if the railroad's optimum service level is also the consumer's optimum use level, that is,

$$\left.\frac{\delta U^C}{\delta y_1}\right|_{y_1 = \bar{y}_1} = 0 .$$

With all consumer activities fixed at levels $\bar{x}_i$, potentially relevant non-marginal economies exist where

$$\left.\frac{\delta U^C}{\delta y_1}\right|_{y_1 = \bar{y}_1} = 0 \text{ and } U^C(\bar{x}_i, y_1) > U^C(\bar{x}_i, \bar{y}_1)$$

for any $y_1 \neq \bar{y}_1$. Service level y_1 may be greater or less than level $\bar{y}_1$. While incremental changes in service could not perceptibly please the consumer, the consumer might be willing to seek a significantly higher or lower level of service. Non-marginal changes in railroad service level will be irrelevant when consumers are satisfied with service level $\bar{y}_1$, that is

$$\left.\frac{\delta U^C}{\delta y_1}\right|_{y_1 = \bar{y}_1} = 0 \text{ and } U^C(\bar{x}_i, y_1) \leq U^C(\bar{x}_i, \bar{y}_1)$$

for all $y_1 \neq \bar{y}_1$.

Pareto relevant externalities are a subset of potentially relevant externalities. To be Pareto relevant, the effective marginal net gain to the consumer of an incremental service unit must exceed the marginal net loss to the railroad producer for deviating from a private optimal output level. Effective marginal consumer net gain is characterized first by sufficient resource endowment or resultant gain in marketable values to compensate the railroad for opportunity losses, and secondly, by consumer gain above opportunity losses from foregone consumer activities. A marginal Pareto relevant economy exists, then, where the consumer's marginal rate of substitution of railroad service for some other activity X_j is greater than the company's net marginal rate of substitution of service to link 1 for service to some other link j, that is,

$$\frac{\delta U^C_{y_1}}{\delta U^C_{x_j}} > (-) \left[\frac{\delta U^R_{y_1}}{\delta U^R_{y_j}} - \frac{\delta E^R_{y_1}}{\delta E^R_{y_j}} \right]_{y_1 = \bar{y}_1}.$$

When the consumer is willing and able to pay the incremental costs of added service units, where these payments are not communicated in the market place, a marginal Pareto relevant economy exists. A marginal Pareto relevant diseconomy is defined as

$$(-) \frac{\delta U^C_{y_1}}{\delta U^C_{x_j}} < \left[\frac{\delta U^R_{y_1}}{\delta U^R_{y_j}} - \frac{\delta E^R_{y_1}}{\delta E^R_{y_j}} \right]_{y_1 = \bar{y}_1}.$$

When the consumer is willing and able to pay the company's opportunity losses of unit reductions in service, a Pareto relevant marginal diseconomy exists.

Buchanan and Stubblebine complete their definitions of externalities with a less than satisfactory definition of non-marginal Pareto relevant economies and diseconomies. For discrete changes in activity level Δy_1 a definition for non-marginal Pareto relevant economies is stated in a manner similar to that for marginal economies, replacing point slopes with ratios of arc slopes,

$$\frac{\Delta U^C/\Delta y_1}{\Delta U^C/\Delta x_j} > (-) \left[\frac{\Delta U^R/\Delta y_1}{\Delta U^R/\Delta y_j} - \frac{\Delta E^R/\Delta y_1}{\Delta E^R/\Delta y_j}\right]_{y_1 = \bar{y}_1}$$

where Δy_1 is equivalent on both sides of the definition. Arc slopes are sensitive to the range defined by Δ for any except linear functions. Permitting this definition to serve as a conceptual guide, a non-marginal Pareto relevant externality exists when the consumer's rate of substitution of rail service for some consumer activity exceeds the net rate of substitution of service to link 1 for service to some other link j. Translation of this conceptual definition to a measurement tool must be done with care.

Pareto relevant externalities imply that with proper expression, the consumer could encourage the producer to adjust activity levels leaving the consumer better off and the producer no worse off. Where the subject activity can be jointly consumed, a number of consumers can collectively express a joint value for activity adjustment, assuming costs of organization and transaction do not exceed net consumer gains after compensating the producer. Allowing P local persons to act collectively with organizational costs C_o, there exist marginal or nonmarginal Pareto relevant economies of railroad service level when

$$\sum_{p=1}^{P} \frac{\delta U^{Cp}_{y_1}}{\delta U^{Cp}_{x_j}} - C_o > (-) \left[\frac{\delta U^R_{y_1}}{\delta U^R_{y_j}} - \frac{\delta E^R_{y_1}}{\delta E^R_{y_j}}\right]_{y_1 = \bar{y}_1}$$

or

$$\sum_{p=1}^{P} \frac{\Delta U^{Cp}/\Delta y_1}{\Delta U^{Cp}/\Delta x_j} - C_o > (-) \left[\frac{\Delta U^R/\Delta y_1}{\Delta U^R/\Delta y_j} - \frac{\Delta E^R/\Delta y_1}{\Delta E^R/\Delta y_j} \right]_{y_1 = \bar{y}_1}$$

respectively.

Pareto relevant externalities may exist in the presence of private producer equilibrium. Objective maximizing firms select activity levels $\bar{y}_1$ where added gains equal added losses for marginal output changes. For nonmarginal output changes, firms select activity levels where gains from a possible activity level are greater than or equal to opportunity losses. With numerous market alternatives for resource use, the firm will be constrained near to the equality of gains and opportunity losses. Thus at private producer equilibrium the bracketed right hand terms of preceding definitions equal zero. To the extent that the consumer group is willing and able to financially stimulate a deviation away from private producer equilibrium, a Pareto relevant externality still exists.

Pareto equilibrium may occur at a production level other than $\bar{y}_1$, say y_1^*. Pareto equilibria for marginal and non-marginal railroad output changes are defined by the previous definitions of marginal and non-marginal Pareto relevant economies, where inequalities are replaced by equalities and organization costs, C_o, are zero. Where the sum of consumer gains equals the opportunity loss to the railroad from deviating from private equilibrium production, the consumer group would be either unwilling or unable to compensate further production adjustments. When this definition is fulfilled at a production level other than private equilibrium output level, $\bar{y}_1$, relevant externalities are abated. Consequently, the mere existence of external effects is not a sufficient condition for private collective or public compensatory action. Where gains from internalization are less than concomitant losses, one party must lose which violates the Pareto criterion.

Willingness and ability to pay for higher service levels or retention of service establishes an effective demand function depicting marginal valuation of service units. A demand function for alleviation of external effects is not sufficiently well expressed in an active market to communicate with producers in terms of price signals. Willingness and ability to produce and offer extra-equilibrium service levels for compensation of marginal losses, establishes a supply function for the non-existent market.

Turvey provides a geometric interpretation of Buchanan and Stubblebine's definitions which permit representation of demand and supply functions for internalization of values.[2] In Figure 3, curve CC' is the aggregate consumer marginal valuation function for various railroad service levels. Aggregation of marginal values is achieved for jointly consumed services by vertical summation of individual demand relationships. Curve RR' represents the railroad company's marginal loss function from incremental service levels.

Marginal Pareto equilibrium exists at railroad service level y^*_{1m}. Output y^*_{1m} is the competitive equilibrium output sufficient to fulfill a normative goal of efficient resource allocation, where marginal consumer valuation equals marginal producer cost. If consumers could persuade the government to force the railroad to operate at "desired" service levels, consumers would perceive zero cost and output OC' would be

[2]Ralph Turvey, "On Divergences Between Social Cost and Private Cost," *Economica* 30 (1963), 309-313.

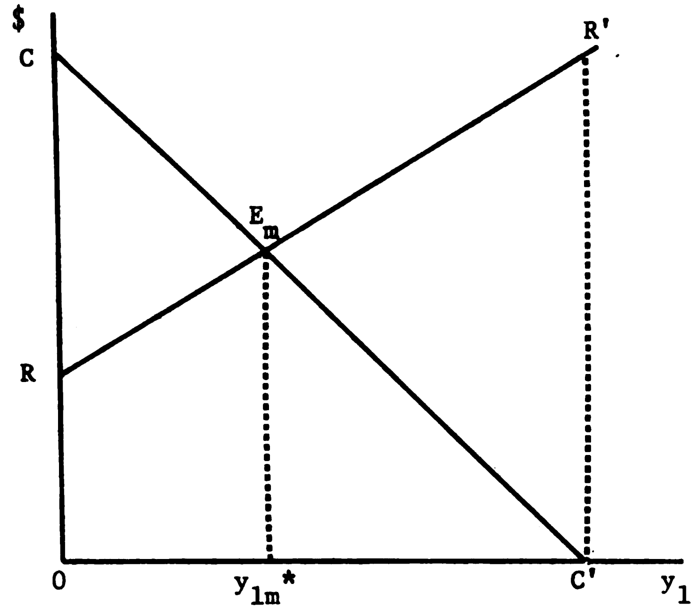

Figure 3.

produced, at a loss to the railroad of ORR'C' and a net loss to society of $C'E_mR'$. The railroad and, consequently, other shippers and communities would, in effect, be subsidizing shippers and communities along link 1. This situation is analogous to that currently resulting from ICC rejection of abandonment applications.

If the consumer was to compensate the railroad for marginal losses, the consumer would buy service level y^*_{1m} where marginal gain just equals marginal cost of compensation. The consumer would pay the railroad $ORE_my^*_{1m}$ dollars and receive a net gain of RCE_m dollars. This situation is analogous to that expected to result from application of principles established in the Regional Rail Reorganization Act.

The non-marginal Pareto "equilibrium" may be approached in slightly different terms, though the concept is the same. This will become apparent as criteria for internalization are developed. Critical non-marginal decision points are those of discontinuity. Where fixed costs associated with discontinuous levels of production must be considered, Turvey's diagrammatic representation fails.

Private Collective and Public Investment Criteria

Normative judgments expressed in the Regional Rail Reorganization Act of 1973 institutionally constrain public investment criteria to Pareto equilibria. States and local governments are granted authority only to act as bargaining agents for various railroad service consuming publics through the price incentive system. Authority to permit and refuse abandonments is retained for federal jurisdiction. Non-federal governments cannot, thereby, force operations which worsen a railroad company's position. Rational public representation would limit transactions to those for which the public is not worse off. Misjudgment of public demand could lead to public overinvestment or underinvestment in railroads.

The definition of Pareto equilibrium appropriate for the abandonment prevention decision is the non-marginal one. Though railroad firms approach disinvestment of individual links with marginal tools, the issue of existence or nonexistence is a non-marginal one from the community's view point. Each side of the definition equation will be developed separately to isolate each actor's values. Representation of each actor's valuations will be integrated to establish a Pareto equilibrium which serves as the private collective and public investment criterion.

Recall from Chapter III that market interactions of railroad companies and shippers will insure continued operation of local service as long as discounted future net operating revenues are equal to or exceed liquidation value of the line, that is

$$\sum_i P_{ik}\, y_{ik} - P^L_{\gamma_o k} \geq 0$$

where P_{ik} and y_{ik} are the discounted net price and quantity of transportation, respectively, for commodity i shipped to and from link k and $P^L_{\gamma_o k}$ is the liquidation value for railroad link k of minimum possible capacity, γ_o. When the value of line liquidation rises above discounted future net earnings, the railroad company will be inclined to retrieve resources held in the line for reinvestment in other enterprises. However, a lump sum subsidy of magnitude U_o, where

$$U_o = P^L_{\gamma_o k} - \sum_i P_{ik}\, y_{ik}$$

$$P^L_{\gamma_o k} - \sum_i P_{ik}\, y_{ik} > 0$$

would restore financial incentive sufficiently to encourage continued local railroad service. An annual subsidy of

$$U_a = \psi\,(P^L_{\gamma_o k} - \sum_i P_{ik}\, y_{ik})$$

$$P^L_{\gamma_o k} - \sum_i P_{ik}\, y_{ik} > 0$$

of indefinite commitment, where ψ is the railroad company's opportunity cost of capital, would establish similarly sufficient incentive. The bracketed term in the non-marginal definition of Pareto equilibrium is equal to U_o in present value terms or equal to U_a in terms of annual flows.

For a P-member community residing along marginal railroad link 1, the aggregate consumer valuation for the line equals the sum of individual consumer valuations

$$\sum_{p=1}^{P} \frac{\Delta U^{Cp}/\Delta y_1}{\Delta U^{Cp}/\Delta x_j}$$

screened through individual income constraints. Where there are R possible kinds of external effects, e_r, caused by the existence of the local rail line for which each person holds a positive, negative or zero value, v_{rp}, the sum of consumers' willingness and ability to pay for line retention equals

$$\sum_{p=1}^{P} \frac{\Delta U^{Cp}/\Delta y_1}{\Delta U^{Cp}/\Delta x_j} = \sum_r \sum_p v_{rp}\, e_r \qquad \begin{matrix} r = 1, \ldots, R \\ p = 1, \ldots, P. \end{matrix}$$

Other consumption opportunities are accounted for by the ranking of projects in individual and governmental budgeting processes. The result is a scalar expressing the community's total willingness and ability to subsidize the railroad for continued operation.

The social bound for resource allocation to service link 1, given normative institutional constraints, occurs where the sum of payments for market and external values equals the liquidation value of the line,

$$\sum_i P_{ik}\, y_{ik} + \sum_r \sum_p v_{rp}\, e_r = P^{L}_{\gamma_o k}.$$

The left hand sum is the total social value of railroad service obtainable from the existence and service on a marginal, minimum capacity line. If total societal value falls short of liquidation value, resources can be used more efficiently elsewhere. From society's point of view, this value requirement may be biased downward since external effects of activities for which railroad resources could be used elsewhere in the railroad system are not recorded in the liquidation value.

The social bound to efficient resource allocation to link 1 assumes costless organization and transaction for internalization of effects, that is, $C_o = 0$. When organizational frictions do exist, these costs must be overcome in addition to compensation given directly to railroad producers. Thus the effective social bound will appear at a resource allocation prescription lower than ideally suggested,

$$\sum_i P_{ik}\, y_{ik} + \sum_r \sum_p v_{rp}\, e_r - C_o = P^L_{\gamma_o}k.$$

Market and external gains must be at least equal to liquidation value plus organization and transaction costs to effectively encourage line retention.

Organizational cost friction is particularly important when

$$P^L_{\gamma_o}k \leq \sum_i P_{ik}\, y_{ik} + \sum_r \sum_p v_{rp}\, e_r \leq P^L_{\gamma_o}k + C_o$$

that is, where organizational cost effectively stifles investment. The form of organization then becomes important in determining the level of organizational cost. Private collective action tends to be effective when small numbers of individuals can identify their mutual interests and collect payments for subsidization at low cost. If a large enough portion of external values are internalized by this procedure, external economies are shed on those positively affected by existence of railroad service but who are outside the private collective.

If the required subsidy cannot be met with the willingness of a few to pay, a larger proportion of the externality affected must be brought into the collective of consumers. As the group expands in size, costs of identification, communication, organization and collection rise.

Identification of those externally affected is not a simple matter. Benefits to local businessmen and employees may be easily identified, though not easily measured. Benefits to those who wish only to keep the railroad for potential future use as an alternative to trucking or as a means to receive very large assemblies if a plant is expanded, are not easily identifiable, even to those individuals harboring such values. Option demands are even more difficult to measure.

Also as the group required for minimum collection grows larger, each individual feels less significant a contributor. The group could disintegrate if individuals developed an attitude of unimportance and withdrew from the group. These detractions to collections erode the sum of values collectible for subsidy payment and detract from resource efficiency.

When a small group of private citizens are unwilling or unable to cover the required subsidy, government may be the least costly form of organization through which to express community desire to subsidize. Government is an existing institution charged with functions of collective representation of the public. Administrative, budgetary and enforcement apparatus are established. The appropriate level of government to assume responsibility for railroad subsidization depends partly upon the bounds of significant influence of the subject line. When nearly all abandonment effects are incident upon local communities, city councils or county commissions may articulate a large portion of non-market demand. When major effects cross county boundaries, the state becomes the smallest unit of government appropriate to internalize the effects of abandonment.

Establishment of new organizations to collect subsidy contributions is an alternative. However, the alternative may be an expensive one. New administrative, budgetary and enforcement apparatus must be established in addition to the duties of subsidization and contracting for service retention. An advantage of local railroad authorities is greater local determination of specific contract elements determining service levels. Authorities for individual lines could not, however, develop the expertise derived from many cases which an agent with broader jurisdiction might gain.

The Externality Account

The technology of benefit-cost accounting provides useful concepts of external effect measurement and, to a more limited extent, tools for this measurement. Given that direct market transactions reveal market values for service and that liquidation value reveals the opportunity cost of maintaining line resources in service, an external benefit accounting procedure is applied to provide a more complete basis for evaluating cost effectiveness of the subsidy activity. Care must be taken to account only for changes in levels of external effects which differ in the community with and without the railroad line under investigation. In other terms, all external effects of abandonment which are measured must be caused solely by removal of the line.

Willingness and ability of citizens to subsidize railroad retention to avoid losses not considered by railroad management has been defined by

$$\sum_r \sum_p v_{rp} \, e_r, \qquad r = 1, \ldots, R \quad p = 1, \ldots, P$$

where v_{rp} is the value held by citizen p for external effect r and e_r is the magnitude of external effect r in natural units. Individual values, v_{rp}, may be either positive or negative and, in principle, for any particular externality there may be a mixture of positive and negative values held by the P concerned citizens.

The objective of this section is to identify potential effects of abandonment unlikely to be considered by railroad management, and to propose measurable, non-monetary impact indicators which may accurately measure changes in level of magnitude of these effects with abandonment. Actual measurement is inhibited by the absence of technical data representative of branch lines. Some empirical application of impact indicators is introduced in Chapter VI. Discussion here is chiefly designed as a conceptual and empirical introduction to non-market valuation of railroad lines.

Individual valuation of external effects is not considered in this analysis. Values on non-market effects are individually generated by wants and desires of individual citizens. Where governments plan to act as collective agents to invest in railroad branch line subsidies, complete multiple objective benefit-cost analysis may be performed with close interaction with decision makers. This form of analysis is highly perishable since the values of a particular group of political leaders are likely to be unique to the group. However, a series of such studies may be useful in the future to assist development of standard operating procedures for branch line analysis, which lies beyond the scope of this research.

Seven external effects of railroad abandonment are considered in the following paragraphs. To properly judge the lasting effects of railroad line closure upon local, state and national communities, a sufficiently broad time frame must be allowed to encompass human and organizational adjustments to the change of transportation services.

Breadth of geographic scope is similarly required to account for resource adjustments outside the locally affected community, resulting from the abandonment.

Employment Effects

A central policy objective of federal and state governments is maintenance of low unemployment rates. Employment effects of railroad abandonment are extremely illusive. Net number of jobs created or destroyed in the economy due to railroad line closure may be used to measure employment effects. Care must be taken to view the economy broadly enough in geographic and temporal perspective to encompass intermediate run labor and capital adjustments. Care also must be taken to isolate jobs created or destroyed by line removal which would not be affected by the normal course of events with retention of the line. Number of jobs affected by abandonment depends upon at least four major economic characteristics of the affected region, availability of transportation substitutes, unemployment rates at various skill levels, mobility of labor and mobility of capital.

Where alternatives exist to direct railroad delivery with minor increases in transport cost, firms may continue operating without railroad service. Jobs are threatened only when firms are forced to close due to loss of railroad service. Transport alternatives are typically numerous. Trailer-on-flatcar and railroad shipment to nearby sidings with local truck assembly or delivery preserve the advantage of low cost, long-haul movement with some added cost of equipment and labor for transferral.

Ability to continue plant operations with increased freight expenses may be summarized in Marshall's conditions for inelastic derived demand. Where the product of an affected firm is essential but unimportant relative to all other inputs into consuming industries and where there exist no good substitutes, the producer firm may pass on increased transport charges to customers. A common barrier to the passing of costs is the presence of substitutes in the market. Identical products and services produced by other firms in the area act as near perfect substitutes in a competitive market. Where location adds little or no market advantage in an otherwise competitive industry, demand for the firm's product may appear perfectly elastic, such that increased transport costs cannot be passed on in higher prices. These firms must bear the burden of abandonment from profits. Where added transport costs cause profits to fall below those to other alternative uses of capital and managerial talent, firms close and jobs are affected.

Secondly, unemployment rates by skill category in the region influence number of jobs affected by line abandonments. Where only frictional unemployment exits in all skill categories, layoff by one closing firm may likely cause only temporary unemployment while other firms bid for the labor services of the affected employees. Where structural unemployment exists in skill categories prevalent in the closing firm, employee layoff may be prolonged for lack of similar local opportunities. Where general area unemployment exists with vacancies in skill categories prevalent in the closing firm, layoff may be again of short duration as employees are absorbed locally.

Third, geographic labor mobility affects the impact of line abandonment on jobs. Labor mobility is dependent upon proximity to industrial and commercial centers, existence of commuting facilities and cultural barriers to movement. Areas in the southern half of Michigan's Lower Peninsula are close to hundreds of employing firms and institutions and well serviced by highway facilities. Commuting to jobs in cities different from the city of residence is commonplace. Areas in Michigan's Upper Peninsula provide fewer nearby locations of employment. Change of employment location is more likely to require a family move than in the Lower Peninsula. Cultural barriers to mobility include racial and religious restrictions by geography and philosophy. Labor immobility tends to narrow opportunities for those affected by abandonment related layoff and intensifies the abandonment impact upon jobs.

Finally, mobility of capital influences the net employment effect of the abandonment decision. Capital associated with local firms is released upon plant closure. Some of this capital may move within the region to other industries, replacing old jobs with new jobs. Capital may move within the industry to plant expansions or erection of new plants in locations with more stable transportation facilities; only job relocation is implied by such moves. Capital may move out of the region to create jobs elsewhere; this does not contribute to employment objectives in the affected region, but new jobs created offset job losses in national perspective. Finally, capital from departing industries may be replaced by capital of industries entering the region to take advantage of vacated facilities and skilled workers.

Local railroad abandonment may create jobs by the implied substitution of labor for capital. Next least costly modes of transport such as trucking, local transshipment and trailer-on-flatcar use relatively more labor than direct railroad delivery. Where firms continue to operate with transportation adjustments, employment in trucking and transfer may increase locally.

Geographical distribution of job effects may affect the willingness of local collective agents to subsidize a railroad line. In national perspective, a job loss occurs only if number of jobs lost is not offset by number of new jobs created. However, a local or state government tends to act to maximize the welfare of individuals within the boundaries of its jurisdiction. Jobs destroyed in a local community serve as an impetus to provide local subsidization of railroad links. This reaction is inefficient in the sense of resource allocation. The larger are the bounds of authority controlled by the acting collective agent, the less will be the incidence of this form of inefficient reaction.

The multitude of labor and capital adjustments makes measurement of abandonment-related job loss nearly impossible. Number of local jobs affected by line closure may be estimated by interviews with railroad users. However, the measure of local jobs affected has no meaning in directing efficient resource allocation, unless applied under severely restrictive assumptions. These assumptions include perfect perishability of capital associated with plants along the line and persistent unemployment in skill categories predominant in railroad using firms.

Economic Rents to Fixed Facilities

Land values and rents to physical assets, constructed under the presumption of continued existence of the railroad, may decline with loss of the railroad. A portion of this decline in values has already been accounted for in the magnitude of discounted transport cost increases. A portion also may have been taken into account by property owners discounting for risk at the point of the initial investment decision and investment in insurance of various other forms.

For firms planning to remain in the region, abandonment related rental losses are wholly accounted for in the discounted value of transport cost increases which cannot be shifted to consumers. The value of properties and structures is the discounted value of their streams of net returns. Since the only difference in net returns to properties with and without a railroad is access to railroad transportation, the additional cost of transportation substitutes is the only decline in net returns which can be isolated to the abandonment decision.

For firms forced to leave the area for lack of railroad service, value to the firm of local properties has fallen below opportunity cost of salvage and possibly below the cost of plant reconstruction at another location. Property losses by firms attributable to the abandonment decision are equal to the discounted stream of marginal revenue product with the railroad, less salvage price without the railroad, less current value of various insurances against risk, less discounted future value of any comparative advantage gained in the move. Tax savings which the firm may collect on the loss also enter individual firm decisions to subsidize, but do not reflect a net economic value.

Gains from comparative advantage in movement are often overlooked. Comparative advantage often drifts away from established plants as time passes. Firms cannot respond immediately due to resource fixities. However, any decline in value of current operations makes the financial reward of relocation relatively more attractive and property losses at the original location are partly offset by an even higher level of rents available at the center of relative production and marketing advantage.

Consumer Price Effects

The objective of social demand estimation is to determine community willingness and ability to subsidize line retention. A simple estimator of price effects is available. Where railroad service is discontinued and local business operations are continued unaltered, the added cost of next least costly transport would be borne by either producers, intermediate consumers of products produced by railroad using firms or consumers of related final products. Incidence of added transport expenses depends upon elasticities of supply and demand at each market level. Where either industry supply is sensitive or demand insensitive to price, at least a portion of added transport expenses may be passed on to consumers. The more elastic is supply and the less elastic is demand, the greater is the proportion of added transport costs expected to be passed on to purchasers.

Bulk fertilizer serves as a good example. Bulk fertilizer satisfies at least two conditions for inelastic derived demand; fertilizer is essential and there are no close substitutes, either physically or geographically. Bagged fertilizer is far more expensive than bulk material, in large volumes. Bulk fertilizer distributors typically service areas of radius not exceeding ten miles, due to the technology of application. Consequently, a large portion of cost increases may be shifted to farm purchasers.

The magnitude of community willingness to pay to avoid abandonment related price effects equals the sum of added transport expenses, regardless of incidence. Where all incremental transport expenses are borne by direct railroad users, all price effects are incorporated in the market bound with consideration of potential revenue enhancement by railroad price discrimination or collective user subsidy. In this situation there are no concomitant consumer price effects. Where a portion of increased transport costs is shifted to consumers, very large portions of the community bear interest in line retention. In both instances, total community willingness to subsidize to avoid price effects of line closure is identical to added transport cost. In empirical applications, consumer price effects will be measured jointly with potential revenue enhancement by market mechanisms. Sufficient information to determine incidence of price effects is not available.

Abandonment and Energy

A useful nonmonetary indicator of stress put upon energy resources as a result of line closure is the change in gallons of fuel consumed without the railroad. This may be calculated by determining the difference in gallons of fuel used with and without the railroad. Gallons of fuel may be estimated by dividing ton-miles of transportation service performed by each mode by the respective transportation-energy efficiency ratio. The ratio is typically reported in units of ton-miles or passenger-miles of output per gallon of fuel input. Consequently, division of ton-miles by the efficiency ratio in ton-miles per gallon results in a measure of fuel in gallon units.

Some estimates of the transportation-energy efficiency ratio have been made for alternative modes of passenger transport and crude, average measures can be calculated for freight transportation. Goss and McGowan estimate that in 1972, the United States consumed nearly 15 x

10^{15} BTU's of petroleum fuel.[3] (One gallon of petroleum is equivalent to 1.3×10^5 BTU's.) Of this energy, 55 percent was consumed in transportation, in 1965, and 60 percent is projected to be consumed in transportation, by 1980. Linear interpolation suggests that 57.3 percent of petroleum energy was used for transportation in 1972. Of energy used in transportation, 3.5 percent is consumed by intercity railroads and 7.0 percent by intercity motor carriers. On the basis of these data, total petroleum energy consumed by intercity railroads and trucks is approximately 2.31 and 4.63 billion gallons, respectively.

The Task Force on Railroad Productivity reported 1972 freight transportation outputs by railroads and motor carriers at 785 and 470 billion ton-miles, respectively.[4] Thus, industry average transportation-energy efficiency ratios may be estimated roughly as 340 ton-miles per gallon for intercity railroads and 102 ton-miles per gallon for intercity trucks. Comparing industry averages, railroad carriage is nearly three and one-third times as efficient as motor carriage, in terms of ton-miles per gallon.

When estimating transportation-energy efficiency ratios for passenger transport modes, Goss and McGowan also found great variability in energy efficiency within modes under various operating conditions.[5] Consequently, comparison of industry-wide averages of energy efficiency is a highly imprecise measure of energy effects of local branch line abandonments. Branch operations entail assembly and distribution operations with short trains and numerous stops and starts. Measures of

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[3]W. P. Goss and J. G. McGowan, "Transportation and Energy -- A Future Confrontation," Transportation, 5 (Summer, 1973), pp. 17-42.

[4]Task Force on Railroad Productivity, Railroad Productivity, p. 3.

[5]Goss and McGowan, "Transportation and Energy," p. 32.

energy effects of line closure will remain imprecise until transportation-energy efficiency ratios are determined for distinct railroad functions. Confidence in the fuel consumption estimator awaits description of its statistical properties.

The value placed upon this non-monetary measure of energy effects must reflect only the demand for fuel preservation over time. Value of fuel in current use is already considered in fuel prices which compose a portion of operating costs of railroads and alternative transport modes.

Environmental Impact

Effects of rail line abandonment upon the environment may be viewed in both local and national dimensions. Three topics of environmental concern relate to air quality, noise levels and susceptibility of citizens to accident. To the extent that local traffic is shifted to trailer-on-flatcar or local transshipment modes, environmental effects of local line abandonment upon exterior regions will be negligible. A shift to long-haul trucking, however, creates additional air, noise and accident effects upon communities along routes to distant origins or destinations. Values associated with environmental effects are to be converted to streams of annual expected net values and subjected to a discounting procedure to arrive at present value.

Local environmental impacts with and without a railroad are uncertain. With a railroad and a given level of motor vehicle traffic density, a local air pollution level is determined by gas and particulate emissions from manufacturing plants, waste disposal plants, motor vehicles and locomotives. Without a railroad, locomotive emissions are removed and increased truck emissions are added. When manufacturing plants are forced to close due to railroad closure, these reductions in local emissions are to be accounted for. However, in broader geographic perspective, relocation of the firm will merely reintroduce similar industrial pollution elsewhere.

Similar accounts of community noise levels may be considered. Abandonment replaces locomotive and train noise with increased noise from trucks. Noise levels have three important characteristics, sound pressure level, duration and location. Sound pressure level, in decibel units, measures the intensity of sound. A train whistle, for example, heard at five hundred feet has a sound pressure level of ninety decibels.[6] Sound intensity within a city bus and the maximum standard for background noise in factories, established by the Department of Labor, are also of ninety decibels. The sound of a truck downgrade has been measured at over one hundred decibels. Though train whistles and truck downgrades are of short duration, operating sounds are sustained for longer periods. Location of noise is important because of the additive nature of sound pressure. One element of noise in a rural area may not be as harmful as one more element of noise in an already noisy urban area.

Differences in susceptibility to accident in a community with and without a railroad are also ambiguous. The net change in accident probability consequent with line closure equals increases in accident probability resultant with abandonment related additional truck trips less the probability of car-train collisions at grade crossings on the line.

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[6]Nancy W. Sheldon and Robert Brandwein, The Economic and Social Impact of Investments in Public Transit (Lexington, Mass.: D.C. Heath and Co., 1973), p. 53.

Probabilities, in units of accidents per ten million vehicle miles, may be multiplied by average dollar valuation of damage in property loss and injury in highway and car-train accidents. Total value of damage in property and injury may be either positive or negative, depending upon the relative expected value of added highway accidents and reduced car-train collisions.

Environmental effects of closing lightly traveled branch lines are likely to be quite small. Since railroad traffic is sparse to begin with, added trucking activity due to abandonment would also be slight. An illustration of the magnitude of traffic diversion to trucks is illustrated in the following section.

Traffic Diversion and Highway Life

One effect of diverting railroad traffic to motor transport may be accelerated deterioration of highways. Accelerated deterioration would reduce highway life causing more intensive roadway repair and more rapid replacement. These are costs to taxpayers except for the value of trucker user charges collected on net truck enterprise units entering the market to replace railroad service.

Measurement of highway life effects of new traffic has been a topic of research by the Michigan Department of State Highways and Transportation. The department's study is designed to determine surface thickness required to produce a standard service life under projected traffic patterns. The procedure requires several steps and makes reference to tables and charts standardized to lower peninsula Michigan traffic patterns.[7] First, average traffic flow is estimated over desired service life. Secondly, commercial traffic volumes are segregated from passenger automobile traffic. Third, all traffic flows by various vehicle types are converted to standard 18-kip single axle weight equivalents for measurement of traffic loading on the highway. The 18-kip single axle unit is not just a unit of weight. Rather the measurement is a standardized unit of vehicle "use" of the roadway resource, developed in road tests conducted over a two year period by the Association of American State Highway Officials. One 18-kip single axle unit is a standardized amount of roadway damage done by passing a single axle of 18,000 pound load over the surface. This is equivalent, for example, to a two-axle tractor pulling a two-axle trailer and a three-axle tandem trailer.

Engineers use these traffic demand measures to determine thickness of pavement and quantities of reinforcing steel material to be embedded in the structure. The measurement may be converted as an economic measuring tool to determine the degree of roadway life deterioration implied by railroad abandonment.

Traffic forecasting begins with an initial average daily traffic measure and is adjusted for expected growth trends. Recent average daily traffic figures are available for every roadway segment in Michigan, reported in sufficiency ratings.[8] If a constant annual rate of

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[7]Fred Copple, "Procedure for Design of Continuously Reinforced Concrete Pavements," Michigan Department of State Highways Research Report No. R-609, Research Project 61F-64(1), October, 1966.

[8]Michigan Department of State Highways and Transportation, Michigan Highways: 1973 Sufficiency Ratings by District, Report No. 153, Interstate and Sufficiency Unit, Transportation Planning Division, Lansing, Michigan, 1974.

traffic growth is anticipated, of rate r, average daily traffic for the entire period is T_n, where

$$T_n = T_o[(1 + r)^n - 1][\frac{1}{r} + \frac{1}{2}]$$

and n is the expected life of the roadway. For approximations assume n = 20 years. The A.A.S.H.O. estimate of average highway life nationwide is slightly less than 20 years.[9]

The long term average daily traffic is divided by two to determine the flow in each direction. The percent of total traffic composed of commercial vehicles is recorded for each roadway segment in the highway department sufficiency ratings. For multiple lane highways, hourly volumes of commercial and passenger traffic moving in one direction are compared with Figure 4 to determine the proportion of vehicles in the right lane at any moment. The right lane is most heavily traveled and is, thereby, the critical lane for decision making. The average daily number of vehicles moving in one direction in the right lane may be determined.

Next, the total number of commercial vehicles in the right lane must be distributed among vehicle types to permit conversion to 18-kip single axle units. Table 21 provides distribution, 18-kip single axle conversion factors and total 18-kip single axle units per hundred vehicles, for three general traffic densities. Vehicle type distribution in the table is based upon Michigan traffic counts during 1964 and 1965. Heavy traffic routes are those connecting interstate commercial centers.

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[9]William W. Hay, An Introduction to Transportation Engineering (New York: John Wiley & Sons, Inc., 1961), p. 391.

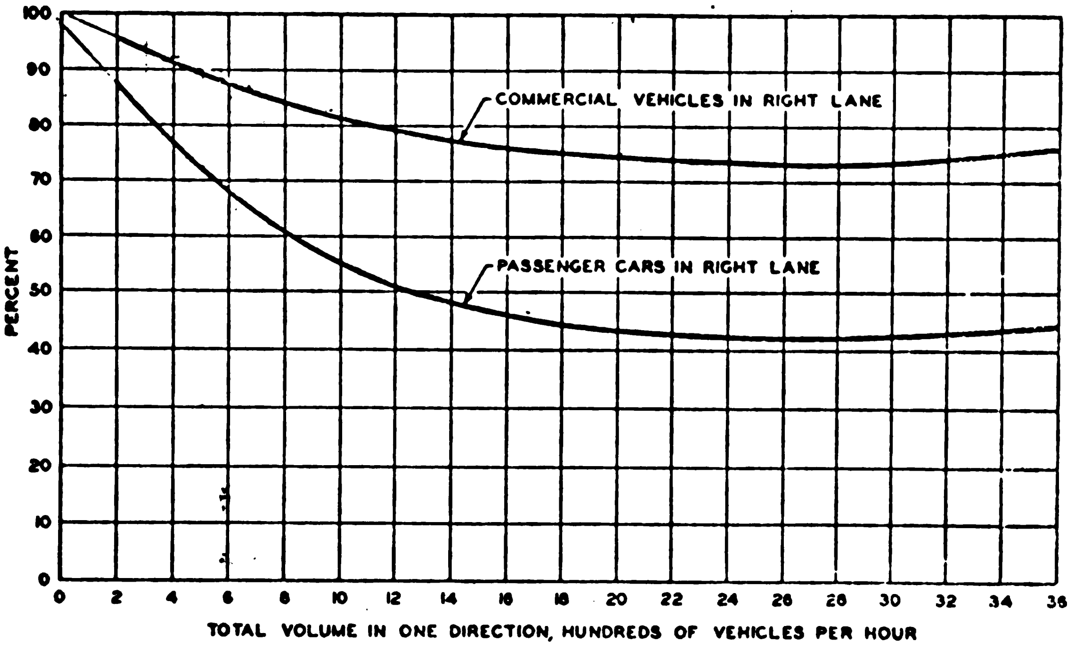

Figure 4. Percent of Commercial Vehicles and Passenger Cars Traveling in the Right Lane for Different Traffic Volumes

TABLE 21. Summary of Commercial Traffic Distribution

Laboratory Codes	Vehicle Type	Light Commercial Traffic			Medium Commercial Traffic			Heavy Commercial Traffic		
		No. Per 100 Commercial Vehicles	Total 18-Kip Equivalent Factors for Given Vehicle*	18-Kip Single Axles per 100 Commercial Vehicles	No. Per 100 Commercial Vehicles	Total 18-Kip Equivalent Factors for Given Vehicle*	18-Kip Single Axles per 100 Commercial Vehicles	No. Per 100 Commercial Vehicles	Total 18-Kip Equivalent Factors for Given Vehicle*	18-Kip Single Axles per 100 Commercial Vehicles
2-1	2	47.2	0.0016	0.08	16.5	0.0016	0.03	7.4	0.0016	0.01
2-2	2D	21.5	0.06	1.29	15.2	0.06	0.91	9.1	0.06	0.55
2-3	3	1.7	0.19	0.32	1.8	0.19	0.34	1.1	0.19	0.21
3-3	2S1	7.2	0.32	2.30	14.2	0.32	4.54	13.3	0.32	4.26
	3S1	0.54	0.76	0.41	--	--	--	0.6	0.76	0.46
3-4	2S2	7.91	0.42	3.32	19.7	0.42	8.27	26.5	0.42	11.13
	2S2L	0.55	0.56	0.53	2.5	0.56	1.40	3.1	0.56	1.74
	3S2L	1.78	0.74	1.32	5.8	0.74	4.29	10.9	0.74	8.07
	3S2	2.45	0.49	1.20	8.0	0.49	3.92	17.0	0.49	8.33
3-5	2S3L1	0.10	1.16	0.12	0.3	1.16	0.35	0.5	1.16	0.58
	2S3	0.05	1.11	0.06	0.1	1.11	0.11	0.1	1.11	0.11
	2S3L	0.09	1.05	0.95	0.3	1.05	0.32	0.7	1.05	0.74
	2S3L2	0.06	1.71	0.10	--	--	--	0.1	1.71	0.17
	2S3LL	0.07	1.02	0.07	0.2	1.02	0.20	0.4	1.02	0.41
	3S3LL	--	--	--	--	--	--	--	--	--
	3S3L	--	--	--	--	--	--	--	--	--
3-6	3S3L2	--	--	--	--	--	--	--	--	--
	3S3	0.2	0.98	0.20	1.1	0.98	1.08	0.4	1.02	0.41
	3S3L1	--	--	--	--	--	--	--	--	--
3-7	3S4	--	--	--	--	--	--	--	--	--
3-8	3S5	--	--	--	--	--	--	--	--	--
4-5	2S1-2	0.6	0.71	0.43	0.7	0.71	0.50	2.9	0.71	2.06
4-6	2S2-2	1.4	1.82	2.55	2.9	1.82	5.28	2.1	1.82	3.82
4-7	2S2-3	1.2	1.06	1.27	2.6	1.06	2.76	0.3	1.06	0.32
4-8	3S2-3	0.5	3.73	1.86	1.0	3.73	3.73	--	--	--
4-9	3S2-4	0.3	2.90	0.87	0.8	2.90	2.32	--	--	--
4-10	3S3-4	0.5	4.34	2.17	0.9	4.34	3.91	--	--	--
4-11	3S3-5	0.6	4.69	2.81	1.3	4.69	6.10	--	--	--
4-12	3S4-5	--	--	--	0.2	6.58	1.32	--	--	--
5-4	2-2	0.6	1.3	0.78	0.7	1.3	0.91	0.8	1.3	1.04
5-5	3-2	0.2	0.65	0.13	0.5	0.65	0.32	0.6	0.65	0.39
5-6	3-3	--	--	--	0.1	0.49	0.05	0.1	0.49	0.05
5-7	3-4	--	--	--	0.1	1.00	0.10	--	--	--
5-8	3-5	--	--	--	0.2	1.43	0.29	--	--	--
6	Bus	2.3	0.004	0.01	0.9	0.004	0.00	1.8	0.004	0.01
	Totals	100.0		25.15	100.0		54.41	100.0		45.05

Source: Fred Copple, "Procedure for Design of Continuously Reinforced, Concrete Pavements," Michigan Department of State Highways, Research Report No. R-609, October, 1966.

Medium commercial traffic roadways are those connecting industrial cities within Michigan, such as the interstate system. Finally, light commercial traffic highways compose the rest of Michigan's state and federal highways. Further studies done since 1966 have shown commercial vehicle type distribution to be quite consistent across locations, within heavy and medium traffic density categories.[10] Variation of vehicle type distribution is more pronounced in the light commercial traffic density group. Two sample studies were taken within the two-county study area which is the subject of empirical application in Chapter VI. These sample studies suggest that the distributions indicated in Table 21 are useful for estimation purposes. Table 22 shows the results of traffic surveys at the Portland scales on Interstate 96 which represents a medium commercial traffic trunkline and at the Ionia scale on Michigan Highway 66 which represents a light commercial traffic highway. Truck type of Table 22 corresponds with laboratory codes in Table 21. Note the similarity in percent distributions of average daily vehicle passages in Table 22 with the generalized distributions in Table 21. Individual truck type 18-kip single axle equivalents were found to have very little variance between location or density category.

Conversion of passenger car traffic is much easier. An average automobile weighing 4,000 pounds has an equivalence of 0.0004 18-kip single axle units. Multiply this conversion factor by the number of passenger vehicles moving one direction in the right lane each day.

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[10]Fred Copple, "Statewide Determination of Highway Loadings and Conversion to 18-KIP Single Axle Load Equivalence," Final Report on a Highway Planning and Research Investigation Conducted jointly between the Federal Highway Administration and the Michigan Department of State Highways and Transportation, Research Report No. R-814, Lansing, Michigan, March, 1973.

TABLE 22. Vehicle Type Distribution and Average Daily Volume on Two Michigan Highways

Portland Scale (I 96)

Truck Type	Average Vehicles, percent		Difference (Avg. daily less the 6-hr avg.)
	Per Day	9 a.m. to 3 p.m.	
2- 1	15.2	16.2	-1.0
2- 2	14.7	17.4	-2.7
2- 3	1.6	1.9	-0.3
3- 3	13.1	14.3	-1.2
3- 4	30.6	25.4	5.2
3- 5	14.1	12.6	1.5
3- 6	0.7	0.7	0.0
3- 7	0.1	0.0	0.1
3- 8	0.1	0.0	0.1
4- 5	0.9	1.0	-0.1
4- 6	2.4	2.5	-0.1
4- 7	1.6	1.7	-0.1
4- 8	0.5	0.5	0.0
4- 9	0.3	0.4	-0.1
4-10	0.7	0.8	-0.1
4-11	0.8	1.1	-0.3
4-12	0.2	0.2	0.0
4-13	0.0	0.0	0.0
5- 4	0.5	0.6	-0.1
5- 5	0.3	0.3	0.0
5- 6	0.0	0.0	0.0
5- 7	0.1	0.1	0.0
5- 8	0.1	0.1	0.0
6- 2	1.2	1.3	-0.1
6- 3	0.2	0.2	0.0
6- 4	0.2	0.1	0.1

Ionia County (M 66)

Truck Type	Average Vehicles, percent		Difference (Avg. daily less the 6-hr avg.)
	Per Day	9 a.m. to 3 p.m.	
2- 1	41.1	40.8	0.3
2- 2	28.8	29.8	-1.0
2- 3	2.9	2.8	0.1
3- 3	5.8	5.9	-0.1
3- 4	11.5	11.3	0.2
3- 5	3.2	3.1	0.1
3- 6	0.3	0.3	0.0
3- 7	0.0	0.0	0.0
3- 8	0.0	0.0	0.0
4- 5	0.6	0.5	0.1
4- 6	0.8	0.7	0.1
4- 7	0.8	0.6	0.2
4- 8	0.1	0.2	-0.1
4- 9	0.1	0.1	0.0
4-10	0.1	0.1	0.0
4-11	0.2	0.3	-0.1
4-12	0.0	0.0	0.0
4-13	0.0	0.0	0.0
5- 4	2.1	2.1	0.0
5- 5	0.1	0.2	-0.1
5- 6	0.0	0.0	0.0
5- 7	0.0	0.0	0.0
5- 8	0.0	0.0	0.0
6- 2	1.1	1.0	-0.1
6- 3	0.0	0.0	0.0
6- 4	0.3	0.0	0.3

Source: Fred Copple, "Statewide Determination of Highway Loadings and Conversion to 18-kip Single Axle Load Equivalence," Michigan Department of State Highways and Transportation, Research Report No. R-814, March, 1973.

After calculating total average daily 18-kip single axle units passing over the highway during the next 20 years, impact of additional traffic upon highway life may be viewed using Figure 5. Figure 5 shows the relationship between daily load in one lane and service life for three surface thicknesses. First, compare current traffic volume with the figure to determine whether service life is yet being threatened. Secondly, add anticipated traffic diversions caused by railroad abandonment to initial average daily travel. Then repeat the procedure for calculating traffic load. The difference in expected service life of a roadway of given thickness may then be approximated from the figure.

An example will help. To observe an unrealistically concentrated traffic diversion to a single highway, suppose all Clinton County railroad traffic was diverted to truck at a conversion rate of three truckloads per railroad carload. Let all traffic move toward St. Johns and on to Lansing by way of U.S. Highway 27. What is this maximum effect of traffic diversion on service life of U.S. 27 between the two cities? A total of 579 carloads were generated or terminated at Fowler, St. Johns and Ovid during 1973. Multiplying times three converts carloads into 1937 truckloads annually or 4.76 vehicles added to average daily travel. Assume traffic will be distributed among the large freight trucks in the proportion of medium commercial traffic density, or 0.81 18-kip equivalents per vehicle.

Assume also three alternative annual traffic growth rates, three, six and nine percent. Clinton County is an agricultural county for which a vast majority of originating and terminating shipments service the agricultural industry. Average annual growth in county grain

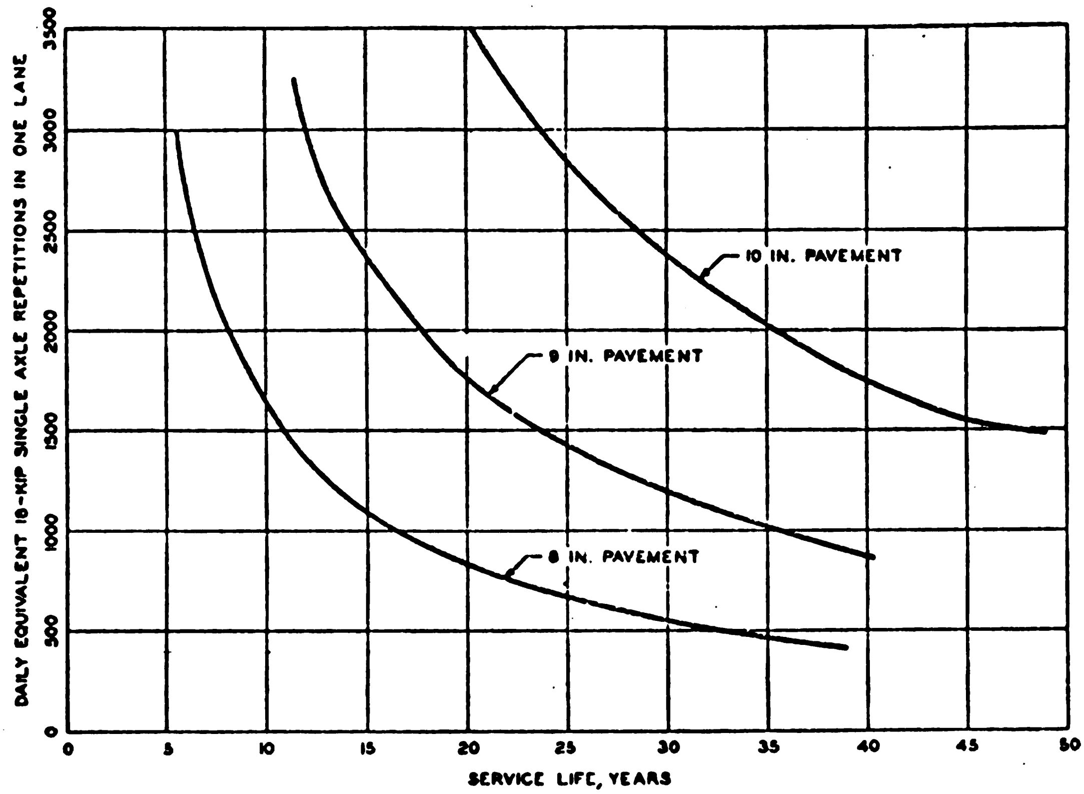

Figure 5. Traffic Loading and Highway Service Life

production was six percent from 1960 through 1970.[11] Growth rates on either side of six percent represent pessimistic and optimistic growth patterns.

Current average daily travel between St. Johns and Lansing is 7400 vehicles, ten percent of which are commercial. U.S. 27 is a four lane highway with an assumed service life of twenty years. Calculations of total current 18-kip single axle units may be followed in Table 23.

Diverted traffic is not sufficient to change the proportion of all traffic which is commercial. Additional 18-kip single axle load units implied by diverted traffic may be calculated as in Table 24. At these levels of traffic diversion the proportion of vehicles traveling in the right lane will not change for the diversion. Assume all traffic is moving in the same direction.

This example has provided not only a procedural exposition, but also perspective on abandonment impacts on highway life. With inflated assumptions of traffic diversion, concentration and distribution among vehicle types, potential diversions of traffic to the highway add only infinitesimally to total daily traffic load and detract imperceptibly from highway life. This should not be interpreted as a final conclusion for all communities. Copple recently showed that distribution of traffic among vehicle types is quite variable between communities serviced by light traffic density highways.[12] Where industrial traffic is expected to be concentrated with very heavy traffic, as from steel or cement

[11]Calculated from Crop Reporting Service data for Clinton County, Michigan.

[12]Copple, "Highway Loadings."

TABLE 23. Calculating Current Traffic Load for U.S. 27 Under Three Assumed Traffic Growth Rates, 1973 Base Year.

Item	Growth Rate		
	3%	6%	9%
1. Initial ADT (Sufficiency Ratings)	7,400	7,400	7,400
2. Percent Commercial (Sufficiency Ratings)	10%	10%	10%
3. Traffic Growth Factor (Formula)	1.36	1.89	2.67
4. Average ADT over 20 years ((1) x (3))	10,091	14,019	19,781
5. ADT each Direction ((4) ÷ 2)	5,046	7,010	9,890
6. Daily commercial vehicles in each direction ((5) x (2))	505	701	989
7. Total hourly volume in each direction ((5) ÷ 24)	210	292	412
8. Proportion commercial vehicles in right lane (Figure 4)	0.96	0.94	0.91
9. Total commercial vehicles in each direction in right lane ((6) x (8))	485	645	900
10. Daily equivalent 18-kip single axles of trucks in right lane ((9) x 54.41) Table 21	263.9	350.9	489.7
11. Autos in each direction ((5) - (6))	4,541	6,309	8,901
12. Proportion autos in each direction in right lane (Figure 4)	0.88	0.83	0.77
13. Autos in each direction in right lane ((11) x (12))	3,996	5,236	6,854
14. Daily equivalent 18-kip single axles of autos in right lane ((13) x .0004)	1.6	2.1	2.7
15. Total daily equivalent 18-kip single axles in right lane ((10) + (14))	265.5	353.0	492.4

TABLE 24. Calculating Diverted and Total Traffic Load For U.S. 27 Under Three Assumed Growth Rates, 1973 Base Year

Item	Growth Rate		
	3%	6%	9%
1. ADT diverted	4.76	4.76	4.76
2. Traffic Growth Factor (Formula)	1.36	1.89	2.67
3. ADT diverted over 20 years ((1) x (2))	6.47	9.00	12.71
4. Proportion commercial vehicles in right lane (Figure 4)	0.96	0.94	0.91
5. Total diverted commercial vehicles in right lane ((3) x (4))	6.21	8.46	11.56
6. Daily equivalent 18-kip single axles of diverted trucks in right lane ((5) x .81)	5.03	6.85	9.37
7. Total traffic load after diversion ((Line 15, Table 23) + (Line 6, Table 24))	270.53	359.85	501.77

producers, community specific sampling may be undertaken by procedures outlined by Copple.

Option Demand

Some persons not currently using railroad services may hold value in retaining the option to use such services at some future time. Since these option demands are not expressed in a currently active market for service, these values are not taken into account by railroad operators. Consequently, option values are external to railroad abandonment decision processes. Weisbrod, the first to formalize the concept of option demand, suggested that option value arises from the infrequent or uncertain purchase of commodities and from the fact that reductions in supply may be functionally irreversible.[13] Weisbrod concludes that "if these consumers behave as 'economic men' they will be willing to pay something for the option to consume the commodity in the future." Zeckhauser adds another determinant of option value which is not related to uncertainty.[14] Consumers may place value in having a wide variety of goods to choose from, even though they may select only a narrow range of goods. Though this value does not appear in producers' profit accounts, the consumer may be willing to pay to maintain such variety, if a mechanism of payment is available.

Option value, based upon both uncertain anticipation in actual use of services and desire for variety of service, is applicable to railroad branch lines. Once abandonment has occurred, renewal of service would

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[13]Burton A. Weisbrod, "Collective Consumption Services of Individual Goods," Quarterly Journal of Economics 78 (August, 1964), 471-477.

[14]Richard Zeckhauser, "Resource Allocation with Probabilistic Individual Preferences," American Economic Review 59 (May, 1969), 546-552.

be possible only at the great cost of reestablishing roadway facilities. Two ready examples of option value in uncertain anticipation of actual future use of a branch line present themselves. One example is a businessman harboring hopes for plant construction, expansion or modification for which the railroad would serve as the least cost means of transportation. Another example is a businessman who perceives existence of railroad service as a hedge against rapidly rising transportation costs, as truck rates rise relative to railroad rates in consequence to rapid fuel price increases. Indeed, the prospects of fuel becoming scarce is very real, making the latter rationale for option value an important consideration.

At least two examples relate to the existence of rail roadway maintaining a variety of opportunities. One example is the view that existence of a variety of services maintains competition in the transportation industry. Current users of motor carriage have expressed a desire for line retention to maintain reasonable truck rates. The argument procedes that mere existence of the option to use railroad maintains an upper limit on motor carrier rates. Another example is the view that existence of many branch lines provides a variety of locations for industry location. This, in turn, maintains a broad range of flexibility for future adjustment of population settlement patterns. One argument is that pruning of the railroad system to mainline routes between major cities will compound metropolitan concentration and inhibit decentralization.

Weisbrod distinguishes two types of products produced by service units with a plant component, services in actual use and stand-by services to nonusers. Both option value in anticipation and option value

value in competition derive from the stand-by services provided by mere existence of the branch line, with concomitant service schedules or service-on-demand rules. Stand-by services have characteristics of collective-consumption goods, in that existence of the branch line provides security of future service at zero marginal cost to added nonusers. Though many individuals with an option value for the line will never use services, these individuals may be willing to pay up to the expected value of future transport cost savings associated with use or competitive bidding. In collecting these payments, the cost to any individual of maintaining the line is spread among all who similarly value the line.

Where probabilities can be assigned to future use or to monopolistic model pricing behavior, option value may be treated as a risk situation rather than as an uncertainty. Collective payment then resembles the risk spreading mechanism of insurance schemes. Where the probability of a particular individual to suffer highly valued catastrophe is small, a community may share the burden of risk by each paying up to their expected value of loss in catastrophe to provide for prevention. Similarly, for a community with a branch line, future railroad service may be insured by individuals paying up to their expected present value of transportation cost savings attributable to existence of the line.

Expected present value of transportation cost savings is composed of an array of possible transport cost savings and an associated set of probabilities of occurrence. The array of cost savings to the businessman expecting plant expansion is a set of present values of anticipated increases in shipment volume times the difference in railroad and next least costly transport rates, over the planning horizon. The array of cost savings to those holding option value in competition is a set of present values of the anticipated difference in motor carrier rates with and without existence of the railroad line, times volume of shipments, over the planning horizon. Probabilities associated with each savings possibility will most likely be subjectively determined by each individual holding an option value for the branch line. Where true uncertainty exists individuals will be unable to determine the value of the railroad option, even though some value is present.

The most effective mechanism for collecting payments representing option value depends upon the distribution of option values. If nearly all option values are held by a small group of businessmen, a group of railroad users may be expanded to include those railroad nonusers holding an interest in maintaining the line. Voluntary contribution or involuntary taxation within the group may then be designed to capture the value of option demand in a private user subsidy. To the extent such a mechanism is effective, option value may provide one more expansion of the market bound.

Where option demands are held by a broader range of citizens, government subsidy from tax revenues may provide a mechanism for expression of option demand. Workers threatened with layoff upon line closure may be willing to pay up to the value of moving expenses required to take another job in another town. Local retailers may be willing to pay up to the expected value of lost profits expected with local economic recession.

From a practical standpoint, the private railroad user and nonuser subsidy provides the easiest means to express option demands. Actual measurement of value is not required. Individuals may apply subjective probabilities to possible transport cost savings and contribute accordingly. The problem with this method is that individuals may wait to see if their contributions are essential before expressing their full value. They may seek a "cheap" ride, if not a free ride. Taxation in the private group and by government requires explicit estimation of expected values of future transportation cost savings and the level of priority to assign to satisfying these option demands relative to the explicit demands and option demands for other services.

Summary

The Regional Rail Reorganization Act of 1973 limits the jurisdiction of states and local governments to Pareto better adjustments for external effects of railroad abandonment. Jurisdiction is limited by requirements of actual compensation of railroads for retention of unprofitable roadway links. Actual compensation shifts financial responsibility for unprofitable branch line operations from producers to consumers of external benefits of existing roadway links. In consequence, external benefits, once enjoyed by consumers at zero price, will be internalized on unprofitable lines and priced at the value of branch line deficit.

Compensation of railroad deficit based upon external benefits accruing to the existence of a branch line raises two problems. First, external effects caused by line abandonment have geographically wide spread incidence. Once long term adjustments are considered, losses to one community appear as gains to another. Subsidies representing efficient resource allocation will require external accounting by agencies with broad jurisdictional boundaries. State governments appear as logical units for valuation, though some spill-overs across state boundaries are highly likely. Secondly, long term valuation of external effects of line abandonment is a difficult procedure. One notable feature of the impact indicators considered previously is their imprecision. Valuation of these roughly measured impacts will require development of a set of standard operating procedures for valuation, by subsidizing authorities.

Market and social bounds to railroad service provision are now complete. Criteria for line subsidization have been derived from individual firm and market equilibria, based upon assumed individual firm profit maximizing behavior constrained by Pareto optimal exchange. These criteria are applied to a regional system of branch lines in the following chapter, to demonstrate procedures of branch line evaluation and to develop understanding of the magnitude of values involved in local railroad branch lines.

CHAPTER VI

APPLYING MARKET AND SOCIAL BOUND MEASUREMENTS: A CASE STUDY

One objective of this investigation is to develop readily useful measurement devices with which to aid railroad line investment decision making. Theoretical definitions of market and social bounds to railroad service provision serve to guide data selection and investment analysis. Available data sources do not provide ideal measures of appropriate revenues, costs and social valuations. Despite the scarcity of ideal data bases, shippers and state agencies require tools of analysis which can be applied in less than thirty days time. ICC abandonment procedures allow the public thirty days, from date of filing, in which to protest removal of a line. For protests to reflect improved allocative efficiency of resources, results of analysis must be available prior to abandonment hearings. Consequently, this chapter is designed to demonstrate use of existing data sources and previously developed estimators, supplemented only by interviews with affected shippers to determine actual freight shipments and receipts.

This demonstration is designed to operationalize a procedure which shipper groups and state agencies may follow to determine whether subsidization of a particular railroad line is justifiable. The procedure as demonstrated is limited to relatively small segments of line in Michigan on which traffic flow is light. Application to major railroad system adjustments addressing broad questions of regional transportation planning would require significant adjustments in assumptions and definitions.

Recall from earlier discussion that the market bound to provision of railroad service exists where discounted future net revenues equal liquidation value of the line,

$$\sum_i P_{ik} y_{ik} = P^L_{\gamma_o} k.$$

The rational region of regulated production exists where gains from maintaining the railroad activity are greater than or equal to the value of the liquidation opportunity. Recall also that the social bound to railroad service provision exists where discounted future net revenue plus the sum of demands not articulated in the market place, less organization and transaction costs, equal liquidation value of the line,

$$\sum_i P_{ik} y_{ik} + \sum_r \sum_p v_{rp}\, e_r - C_o = P^L_{\gamma_o} k.$$

Society may enhance allocative efficiency of resource use by encouraging service continuation as long as the term on the left is greater than or equal to liquidation value. Measurement of each definitional element is attempted in this procedural demonstration, excepting organizational costs. Arguments peripheral to economic measurement, but useful in complete abandonment analysis are included.

A two county region of Michigan was selected to provide a realistic demonstration of procedures. The area selected for this investigation harbors representative intermodal and intramodal interactions of service availability. This permits the realistic opportunity for traffic consolidation from the lines of two railroad companies to the line of one company. Also observable are opportunities for one railroad firm to continue service to some customers at alternative stations.

Clinton and Ionia counties were selected. Each railroad user was personally interviewed to ascertain volume of 1973 freight shipments and receipts. Questions regarding employment and likely reaction to a railroad closing were also asked. Information gathered in this interview process provided the line specific traffic and employment data required for measurement.

The procedure is developed in three steps. First, an economic base study is undertaken to establish likely trends in railroad traffic generations and terminations. A regional transportation survey is also included in this first step to determine the viability of alternative means of transportation. Secondly, discounted net operating revenues and line liquidation value are estimated to determine the magnitude of subsidy necessary to encourage line retention. Estimates are made here under various types of assumptions to demonstrate application to various situations. Finally, nonmarket impacts of abandonment are identified and measured where possible.

Economic and Transportation Base Studies

The economic base study includes surveys of resource endowments and trends of change which have implications on railroad traffic. Population characteristics of growth and mobility influence both the magnitude of traffic movements and the area of influence attached to the particular railroad line. Distribution of business activity among sectors and activity levels determine the nature of railroad traffic. Trends of change in these elements are required for traffic forecasting.

The transportation base study entails a thorough review of highway, railway and waterway facilities available to the area.

Productivity Resource Base

Both Clinton and Ionia counties are primarily agricultural with scattered manufacturing establishments. Population growth is oriented toward the metropolitan center in Lansing. During the decade of the 1960's, the population of Clinton County grew by 2.5 percent annually, above the statewide average growth rate.[1] The 1970 population is recorded at 48,492 persons. More than half of this growth took place in areas with population aggregations of less than 2,500 inhabitants, thereby reinforcing the rural character of the county's population distribution. The working population of Clinton County is quite mobile in that barely 35 percent of people working in the county reside there. Conversely, great numbers of Clinton County residents work for automobile manufacturers and state government in Ingham County, to the south. Mobility between communities makes the distribution of employment and multiplier effects of railroad abandonment unwieldy. Separation of work place and residence also increases the regional size appropriate for internalizing first round indirect effects of railroad investment decisions and increases organizational costs of private collective decision making.

The population of Ionia County grew at an average annual rate of only 0.6 percent during the last decade, below the statewide average. Population of 1970 is recorded at 45,848 persons. By far the greatest

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[1]All population estimates were taken directly from the U.S. Census of 1960 and 1970 or calculated therefrom.

population growth occurred in rural areas; the city of Ionia, the county seat, lost population at nearly the rate at which the county was gaining inhabitants. Fastest growth was recorded in the southeastern corner of the county, the quarter closest to the metropolitan center of Lansing. Ionia county residents are less mobile than are those of Clinton county. Of those reporting place of work, nearly 70 percent worked in their county of residence.

The industrial base of each county reflects a growing orientation toward the metropolitan center and a resulting stagnation of independent manufacturing activity. In Clinton county, the relative importance of manufacturing, wholesaling and transportation and public utilities has declined slightly during the last decade, as shown in Table 25. The profile of business activity for the county is stable, except for major growth in construction activity. The low proportion of employment in manufacturing reflects the fact that 78.7 percent of the population is rural.

Ionia County has experienced shifts of employment from industrial activities to consumer oriented activities, as shown in Table 25. The proportion of nonagricultural business employment in manufacturing has fallen to nearly half of the total during the last decade; wholesale and transportation activities have stagnated. These industrial activities have been somewhat supplanted by contract construction and retail activities. Absolute numbers of manufacturing establishments and manufacturing employment are below 1959 levels.

Low and declining importance of industrial activity suggests a trend unfavorable for industrial traffic generations. Clinton and Ionia counties are becoming rural residential and farming areas with only

TABLE 25. Nonagricultural Employment Distribution in Clinton and Ionia Counties, Michigan 1959-1972

YEAR	TOTAL COUNTY EMPLOYMENT	MANUFACTURING		WHOLESALING		TRANSPORTATION & PUBLIC UTILITIES		CONTRACT CONSTRUCTION		RETAILING	
		No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.
CLINTON COUNTY											
1959	2,663	901	33.8	292	11.0	101	3.8	85	3.2	754	28.3
1965	3,520	1,227	34.9	337	9.6	122	3.5	174	4.9	1,057	30.0
1972	4,880	1,515	31.0	344	7.0	176	3.6	591	12.1	1,255	25.7
IONIA COUNTY											
1959	6,646	4,343	65.3	179	2.7	192	2.9	137	2.1	1,184	17.8
1965	6,461	3,762	58.2	283	4.4	206	3.2	186	2.9	1,283	19.9
1972	7,606	4,149	54.5	204	2.7	223	2.9	264	3.5	1,693	22.3

Source: U.S. Census of Manufactures.

slight increases in industrial activity. Major growth in industrial and wholesale traffic is not anticipated without significant alteration of previous trends. The exception is traffic in building materials supporting expansion of residential construction.

Growth in agricultural railroad traffic may continue to be strong. During the period 1960-1970, aggregate corn, wheat and soybean production climbed more than 6 percent annually in Clinton County and slightly above 3 percent annually in Ionia County.[2] Cattle production declined by 1.25 percent per year in Clinton County, over the same period, and remained stationary in Ionia County. Consequently, projected gains in grain production may be assumed products for export from the region.

Railroad Stock

The two county study area is boxed in at its border by railroad lines of the Penn Central, Ann Arbor, Chesapeake and Ohio and Grand Trunk Western railroads, as shown in Figure 6. The Grand Trunk Western line under investigation runs west from Owosso through the towns of Ovid, St. Johns and Fowler in Clinton County and through the towns of Pewamo, Muir, Ionia and Saranac in Ionia County. The line continues west to Lowell, Grand Rapids and Grand Haven. The Grand Trunk Western railroad has trackage rights for use of the Penn Central line from its intersection west of Grand Rapids to the Grand Trunk ferry system at Muskegon. The primary function of the Clinton-Ionia line is the connection of the ferry system to the rest of the Grand Trunk railroad system. One train passes over the tracks each day, moving west one day and east the next for a total of three round trips each week. During 1972, 95.4

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[2]Percentages are calculations from annual crop production levels recorded by the Crop Reporting Service.

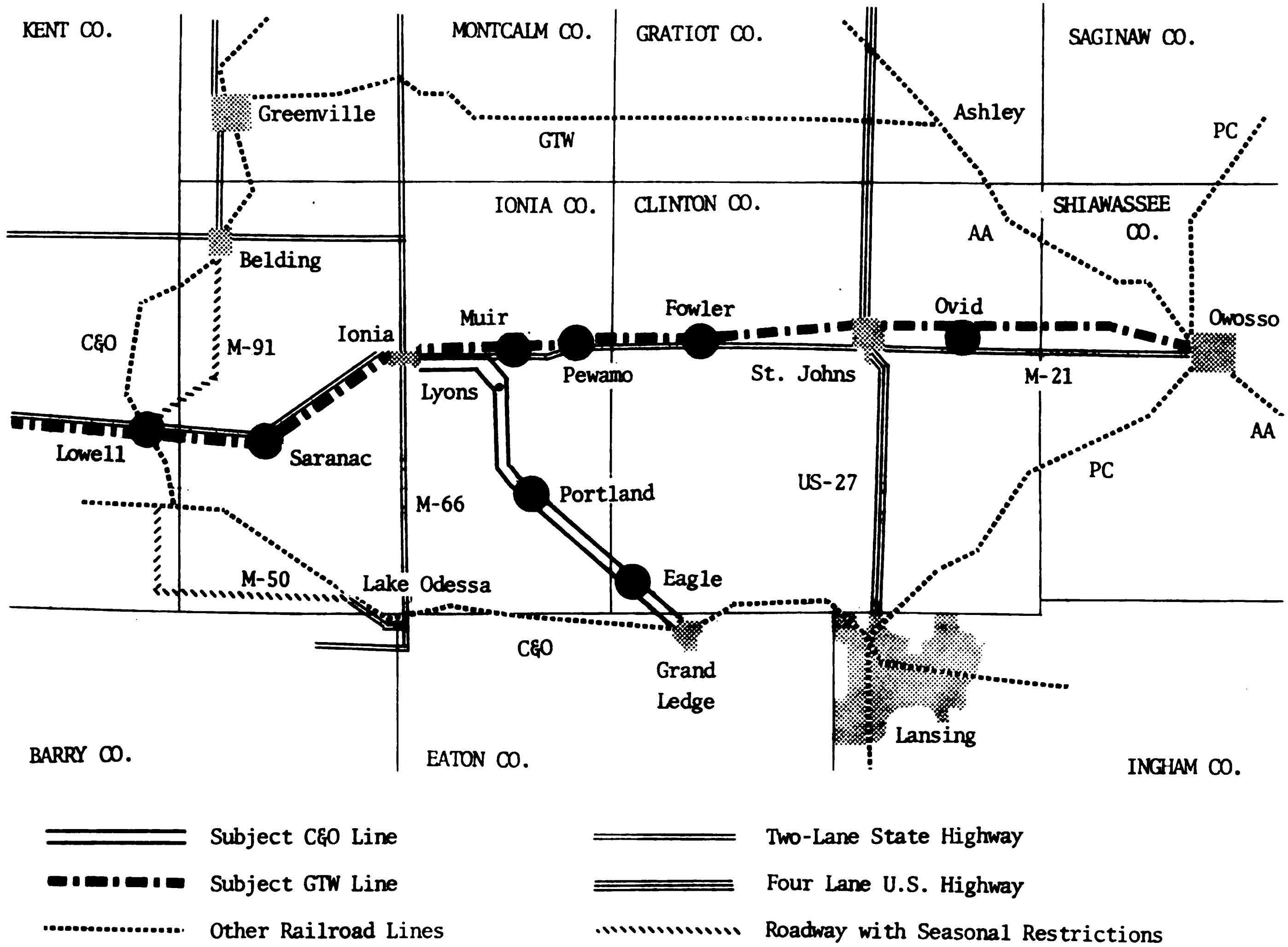
KENT CO.
MONTCALM CO.
GRATIOT CO.
SAGINAW CO.
Greenville
GTW
Ashley
PC
IONIA CO.
CLINTON CO.
SHIAWASSEE CO.
AA
Belding
C&O
M-91
Ionia
Muir
Fowler
Ovid
Owosso
Lyons
Pewamo
St. Johns
M-21
Lowell
Saranac
AA
PC
Portland
US-27
M-66
Eagle
M-50
Lake Odessa
C&O
Grand Ledge
Lansing
BARRY CO.
EATON CO.
INGHAM CO.
Subject C&O Line
Subject GTW Line
Other Railroad Lines
Two-Lane State Highway
Four Lane U.S. Highway
Roadway with Seasonal Restrictions

Figure 6.

percent of carloads generated and terminated on the line west of Owosso represented traffic beyond the two county region.[3]

The Grand Trunk Western also has joint trackage rights on the Ann Arbor line leaving Owosso to the northwest and intersecting a Grand Trunk Western island line at Ashley. The Grand Trunk operates directly west of Ashley to Greenville, the terminus. During 1972 the Grand Trunk Western originated and terminated 2,461 carloads on this line of 61.7 miles, or 39.9 carloads per mile.[4] This traffic density is substantially above that anywhere on the Clinton-Ionia line. One alternative which must be considered is the removal of the Clinton-Ionia line and development of joint trackage rights with the Chesapeake and Ohio railroad for operation over the connecting link between Greenville and Lowell. If this option was available, the Grand Trunk would have continued access to 95 percent of freight traffic while removing the 62 miles of trackage between Owosso and Lowell. The option would require additional movement of each car an added 22 miles. For the 1972 traffic volume west of Lowell of 16,974 carloads, this would entail an added 373,043 car miles each year, disregarding traffic growth or decline.

The Chesapeake and Ohio line under study is a 27.5 mile branch line joining the Detroit-Lansing-Grand Rapids mainline at Grand Ledge, a short distance west of Lansing. Shippers and receivers receive three switches per week originating from the Grand Rapids yard. Greenville is provided switching service on alternative days. Until 1971, the branch received daily switches. A condemned bridge provides a special

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[3]Railroad company traffic reports to the Federal Railway Administration, 1972.

[4]<u>Ibid</u>.

consideration in the abandonment decision. The railroad has two bridges in Portland. The bridge over the Grand River is in good condition. Safety inspection has revealed that the bridge over the Lookingglass River must be replaced at an estimated cost of $250,000. The bridge separates nearly all traffic on the line from the mainline junction.

All cities and towns in the two county area are near trailer-on-flatcar (TOFC) ramps. Nearest ramps are at Lansing, Grand Rapids and Greenville. Other ramp facilities are shown in Figure 7.

Highway Stock

The Clinton-Ionia two county area has excellent access to all-weather and interstate highways, as seen in Figure 6. State Highway 21 runs east and west nearly parallel to the Grand Trunk Western line under investigation. State Highway 27 runs north and south through St. Johns in Clinton County and state Highway 66 traverses Ionia county north and south through the city of Ionia. Interstate 96 connects Lansing and Grand Rapids, Michigan, running along the southern portions of the two counties, passing closely by Eagle and Portland. Each of these roadways is unencumbered by seasonal load restrictions or height and weight restrictions exceptional to state standards. Consequently, each town serviced by railroad has direct access to full year roadway service connecting the two counties with all major industrial cities and all grain handling centers.

The only two state highways in the two county area with seasonal load restrictions are in the western half of Ionia County. Highway 50 west of Lake Odessa has a flexible pavement susceptible to heavy weights during springtime thaws. Lake Odessa is accessible by highway throughout

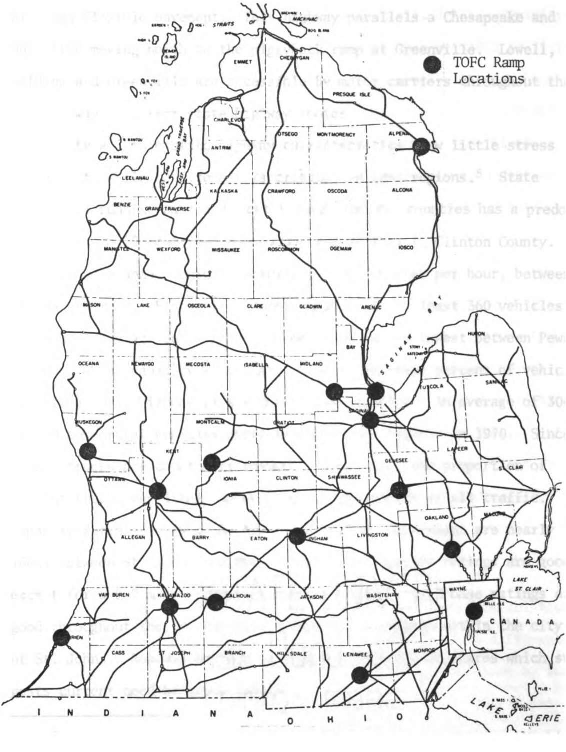
TOFC Ramp Locations
STRAITS OF
MACKINAC
EMMET
CHEBOYGAN
PRESQUE ISLE
CHARLEVOIX
OTSEGO
MONTMORENCY
ALPENA
ANTRIM
LEELANAU
KALKASKA
CRAWFORD
OSCODA
ALCONA
BENZIE
GRAND TRAVERSE
MANISTEE
WEXFORD
MISSAUKEE
ROSCOMMON
OGEMAW
IOSCO
MASON
LAKE
OSCEOLA
CLARE
GLADWIN
ARENAC
HURON
BAY
SAGINAW
OCEANA
NEWAYGO
MECOSTA
ISABELLA
MIDLAND
TUSCOLA
SANILAC
MUSKEGON
MONTCALM
GRATIOT
LAPEER
KENT
GENESEE
ST. CLAIR
OTTAWA
IONIA
CLINTON
SHIAWASSEE
OAKLAND
MACOMB
ALLEGAN
BARRY
EATON
LIVINGSTON
WAYNE
LAKE ST. CLAIR
VAN BUREN
KALAMAZOO
CALHOUN
JACKSON
WASHTENAW
CANADA
CASS
ST JOSEPH
BRANCH
HILLSDALE
LENAWEE
MONROE
LAKE ERIE
INDIANA
OHIO

Figure 7.

the year from the east. State Highway 91 between Lowell and Belding also has flexible pavement. This highway parallels a Chesapeake and Ohio line moving north to the piggyback ramp at Greenville. Lowell, Belding and Greenville are accessible by motor carriers throughout the year by way of direct state highway routes.

State and interstate highway characteristics show little stress on capacity while road repair is critical in some regions.[5] State Highway 21 running east and west through the two counties has a predominant width of 20 feet in Ionia County and 24 feet in Clinton County. The minimum planned vehicle capacity is 250 vehicles per hour, between Pewamo and Muir. Elsewhere planned capacity is at least 360 vehicles per hour. Average daily travel is moderate and is lowest between Pewamo and Muir where capacity is lowest. Nine to thirteen percent of vehicles traveling rural Highway 21 are commercial vehicles. An average of 300 to 500 commercial vehicles daily traveled this highway in 1970. Since pickup trucks are counted as commercial vehicles, the proportion of freight trucks may likely be well below ten percent of all traffic. The capacity ratings assigned by the state highway department are nearly ideal between St. Johns and Muir. Elsewhere capacity ratings are good except for a 0.2 mile segment in downtown Ionia. Road base ratings are good throughout the two counties except for a segment within the city of St. Johns. Roadway surface ratings are critical in places which suggests current need of major repair.

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[5]Michigan Department of State Highways and Transportation, Michigan Highways: 1973 Sufficiency Ratings by Districts, Report No. 153, Interstate and Sufficiency Unit, Transportation Planning Division, Lansing, Michigan, 1974.

State Highway 27 through St. Johns is a four lane highway with planned capacity of 1,450 vehicles per hour south of St. Johns. Capacity tapers downward north of the city. Predominant highway width is 22 feet. Average travel is between 7,500 to 8,000 vehicles daily between Lansing and St. Johns, of which about ten percent is composed of freight and pickup trucks. Capacity, surface and safety ratings are critical on the periphery of Lansing and within St. Johns, suggesting current need for major highway adjustment. St. Johns appears a highway system bottleneck to movement in all four directions.

State Highway 66 serves as the major access route from Ionia to Interstate 96. The highway is predominantly 24 feet wide and built to serve a maximum of 850 vehicles per hour. Only a small proportion of traffic is composed of commercial vehicles, five to nine percent on the various segments. In 1970, an average of 430 commercial vehicles daily used this highway. Capacity, surface and safety ratings are critical over more than half of this highway within Ionia County. The remainder of the roadways to Belding and Greenville are rated well for capacity and condition.

Estimating Market Values and Private Subsidy Potential

Estimation of railroad line market valuation requires calculation of line liquidation value and discounted net revenues. The difference between these values represents the surplus or deficit obtained by the railroad firm for continued operation. The magnitude of deficit provides a measure of subsidy required to encourage continued operation.

Line Liquidation Value

Liquidation value of a railroad line segment is calculated using opportunity cost estimators developed in Chapter III. Opportunity cost parameters have been estimated using data contained in ICC questionnaires accompanying abandonment applications for Michigan lines. Recall that liquidation value is the sum of net material and land salvage value, property tax savings and nonvariable maintenance costs avoided, less joint facility rent losses,

$$P^{L}_{Y_O k} \equiv S + T + .43M - J.$$

Rehabilitation expenses are added when restoration of track and structures is required for continued operation.

Estimation of liquidation value for the example Grand Trunk Western and Chesapeake and Ohio lines is demonstrated in Tables 26 and 27, respectively. Gross salvage value and removal cost are calculated using estimators developed in Chapter III and repeated at the bottom of each table. The difference of these two measures provides an estimate of net material salvage value. The current opportunity value for railroad land should be added to the salvage estimate. Land values for these example lines were not available.

Total annual maintenance expenditures are calculated using the maintenance cost estimator repeated at the bottom of each table. Forty-three percent of this estimate represents nonvariable maintenance costs which are avoidable only by abandonment or neglect. The present value of the nonvariable maintenance cost stream over an indefinite period is calculated by discounting at an eight percent rate. This rate is

TABLE 26. Calculation of Line Liquidation Values: Grand Trunk Western from Owosso to Lowell, Michigan

Station	Distance (Miles)	Gross Salvage Value	Removal Cost	Net Salvage Value	Avoidable Maintenance Cost	Liquidation Value Less Land Value	Cumulative Liquidation Value
Owosso	--	--	--	--	--	--	--
Ovid	10.0	$54,844.10	$61,787.90	-$ 6,943.80	$159,345.63	$152,401.83	$152,401.83
St. Johns	9.1	$47,120.42	$55,837.38	-$ 8,716.96	$143,758.23	$135,041.27	$287,443.10
Fowler	10.0	$54,844.10	$61,787.90	-$ 6,943.80	$159,345.63	$152,401.83	$439,844.93
Pewamo	5.8	$23,124.02	$34,502.88	-$11,378.86	$ 87,248.80	$ 75,869.94	$515,714.87
Muir	4.6	$16,225.53	$26,997.07	-$10,771.54	$ 67,482.28	$ 56,710.74	$572,425.61
Ionia	8.3	$40,662.53	$50,588.11	-$ 9,925.58	$129,904.05	$119,978.47	$692,404.08
Saranac-Lowell	14.2	$96,688.48	$89.912.94	$ 6,775.54	$229,804.06	$236,579.60	$928,983.68

Gross Salvage Value: $1{,}634.71\ D + 433.97\ D^2 - 4.90\ D^3 - 26{,}788.85\ UP$

Removal Cost: $5{,}504.69\ D + 89.21\ D^2 - 2.18\ D^3 - 51{,}234.82\ UP$

Maintenance Cost: $2{,}372.97\ D + 93.06\ D^2 - 3.39\ D^3 + 11{,}192.67\ UP$

D = Distance

UP = 1 if in Upper Peninsula

= 0 otherwise

TABLE 27. Calculation of Line Liquidation Values: Chesapeake and Ohio from Grand Ledge to Ionia, Michigan

Station	Distance (Miles)	Gross Salvage Value	Removal Cost	Net Salvage Value	Avoidable Maintenance Cost	Rehabilitation Cost	Liquidation Value Less Land Value	Cumulative Liquidation Value
Grand Ledge	--	--	--	--	--	--	--	--
Portland	11.7	$ 70,684.36	$ 73,125.31	-$2,440.95	$188,518.78	$250,000	$436,077.83	$436,077.83
Ionia	15.8	$114,837.56	$100,645.88	$14,191.68	$254,523.48	$250,000	$518,715.16	$954,792.99

Gross Salvage Value: $1,634.71\ D + 433.97\ D^2 - 4.90\ D^3 - 26,788.85\ UP$

Removal Cost: $5,504.69\ D + 89.21\ D^2 - 2.18\ D^3 - 51,234.82\ UP$

Maintenance Cost: $2,372.97\ D + 93.06\ D^2 - 3.39\ D^3 + 11,192.67\ UP$

D = Distance

UP = 1 if in Upper Peninsula

= 0 otherwise

equivalent to average railroad bond yields during 1972. The bond rate is assumed representative of railroad firms' cost of capital.

Property tax savings are assumed to have no influence upon railroad investment decisions. Taxation of railroad property in Michigan is based upon company operating revenues, car miles and engine miles as well as real property. Since revenues and traffic are typically small on lightly traveled lines, only small tax savings are anticipated with liquidation. Lacking a high quality property tax estimator, influences of taxation are disregarded. Joint facility rent losses are not relevant to these examples, since no joint trackage contracts are held.

Rehabilitation expenses become important to the investment decision on the Chesapeake and Ohio line. Bridge reconstruction over the Lookingglass river in Portland requires a $250,000 expenditure, avoidable only by ceasing operations. Addition of rehabilitation expenses is demonstrated in Table 27. No extraordinary restoration appears necessary on the Grand Trunk Western Line.

Liquidation values have been estimated for each marginal link and successive cumulations. Cumulative measurements are calculated as the sum of marginal values. For example, viewing the next to last column of Table 26, by abandoning the marginal link from Ovid to St. Johns, the Grand Trunk Western could make or save an estimated $135,041. The last column of Table 26 reveals that estimated liquidation earnings or savings available by abandoning the entire line between the mainline connection at Owosso and St. Johns is $287,443. Estimated liquidation values represent the opportunity cost to the railroad from continued operation, less the opportunity value of land.

Estimating Discounted Future Net Revenues and Required Subsidies

Net operating revenue is the difference between gross railroad income attributable to the line and operating cost attributable to the line. Estimation of discounted net revenue attributable to a line requires a four step calculation procedure. First, total operating cost to the railroad system for each type of shipment is calculated. A shipment type is characterized by commodity and distant origin or destination location. Secondly, total railroad system revenues are determined for each type of shipment. Third, operating cost and revenue attributable to the line segment under investigation are estimated, for each shipment type, by applying a cost and revenue division factor. Net revenues attributable to the study line are obtained by subtracting attributable costs from attributable revenues. Finally, traffic growth factors are applied to develop a stream of forecasted traffic. The anticipated traffic stream is converted to a stream of net revenues and discounted to provide an estimate of the present value of net operating revenues attributable to the line. The procedure is outlined and applied to an example shipment type in Table 28.

Regional average system costs of operating particular kinds of cars with specified load and distance characteristics have been measured by the ICC's Bureau of Accounts.[6] Relevant carload expenses are those which vary with traffic over the long term. Line specific traffic information collected by interviews with railroad users must include commodity hauled, distant origin or destination and average tons per load.

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[6]Interstate Commerce Commission, Bureau of Accounts, Railroad Carload Cost Scales by Territories for the Year 1970, Statement No. ICl-70, Washington, D.C., May, 1973.

TABLE 28. Procedure for Estimating Discounted Net Revenue Attributable to Railroad Branch Lines: An Example*

Line	Description	Source	Example Value
	A. Railroad System Cost		
(1)	Type of equipment	Shipper interview	Covered hopper
(2)	Shipment distance	Shipper interview	644 miles
(3)	Average carload weight	Shipper interview	2,000 cwt.
(4)	Variable cost/cwt.	ICC cost scales, Table 1	$0.225/cwt.
(5)	Variable carload cost	(3) x (4)	$450.00
(6)	Number of carloads	Shipper interview	25
(7)	1970 Railroad system cost of shipment type	(5) x (6)	$11,250.00
	B. Railroad System Revenue		
(8)	Freight rate	Rate consultant (or shipper interview)	$0.81/cwt.
(9)	Shipment weight	(3) x (6)	50,000 cwt.
(10)	Railroad system revenue	(8) x (9)	$40,500.00
	C. Cost and Revenue Division		
(11)	Company distance traveled	Map measurement	102 miles
(12)	Company portion of haul, "a"	(11) ÷ (2)	0.16
(13)	Origination-termination cost	ICC cost scales Table 2	$101.26
(14)	1970 company share of carload cost	$(12)((5)-(13))+\frac{1}{2}(13)$	$105.87
(15)	Cost and revenue division factor	(14) ÷ (5)	0.24
(16)	1970 cost attributable to branch	(7) x (15)	$2,700.00
(17)	Carload cost inflator	Compounding by wage growth rate	1.3395
(18)	1974 cost attributable to branch	(16) x (17)	$3,616.65
(19)	1974 revenue attributable to branch	(10) x (15)	$9,720.00
(20)	1974 net operating revenue attributable to the branch	(19) - (18)	$6,103.35
	D. Traffic Forecasting and Net Present Values		
(21)	Opportunity cost of capital	Railroad bond yield	$0.08
(22)	Annual traffic growth rate	Economic base study	0.06
(23)	Discounted traffic growth factor	$\sum_{t=1}^{20} \frac{(1 + (22))^t}{(1 + (21))^t}$	16.53
(24)	Discounted present value of net operating revenues attributable to branch (traffic growth)	(20) x (23)	$100,888.37
(25)	Discounted present value of net operating revenues attributable to branch (stationary traffic)	(20) ÷ (21)	$76,291.88

*The example shipment type is outbound movement of twenty-five 100-ton covered hopper cars of corn destined for Philadelphia, from St. Johns, Michigan.

Assignment of shipments to types of railroad equipment is possible with knowledge of commodity hauled. Origins and destinations are translated into railroad mileage using standard intercity railroad mileage tables. Mileage conversions must be accurate only to the nearest fifty miles.

Given distance, load weight and type of equipment, variable cost per hundredweight may be taken directly from the ICC cost table for the official region excluding New England. Michigan is a part of this region. Multiplication of unit cost by actual load weight provides a carload variable cost estimate. Multiplication of carload cost by number of cars involved in each type of shipment results in an estimate of total long run variable cost to the railroad system for operating this traffic. Commodity volumes intended for railroad movement but diverted to other modes for lack of railroad equipment should be added before total operating cost is calculated.

Total railroad system revenue may be determined for each type of shipment in one of two ways. One method is to collect actual railroad freight revenues from individual bills of lading during the shipper interview process. This task is often very difficult since many consignees return bills of lading to consignors or to accounting offices, retaining no local record of freight bills paid. A second method is to provide a freight rate consultant with commodity, volume and origin-termination data and purchase published freight rates for each type of local shipment. Published rates multiplied times shipment volumes yield total revenues accruing to the railroad system from particular types of shipments. The latter procedure was used in this demonstration. By either method, shipment volumes intended for railroad carriage but diverted to other modes for lack of railroad equipment should be added before total revenue is calculated.

The third task is to divide system costs and revenues between participating carriers to isolate net revenues realized by the company owning the subject line. A recent study completed for the Federal Railroad Administration by R. L. Banks and Associates, Inc., suggests a method of revenue separation treating branch lines as "isolated operating entities."[7] Complete isolation is appropriate for feasibility analysis of the short line alternative, but not for the subsidization alternative. Branch lines are parts of larger company systems. Continuation of service will cause company revenue gains of half the origination-termination charge and a portion of remaining revenues proportional to the company's share of line haul distance. Thus, revenue is determined not only by on-branch operation, but also by the amount of service performed by other portions of the company's system. Costs are incurred similarly. Terminal costs are accrued on the subject branch along with some line-haul service expense. Costs are also incurred in off-branch line-haul service. Both on-branch and off-branch revenues and costs are attributable to the branch, for these revenues and costs are caused by shipments originating and terminating on the branch. Discontinuance of service would result in removal of all company revenues and costs associated with shipments to and from the branch.

A simple cost and revenue division factor may be applied for calculation of costs and revenues attributable to the subject line. For

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[7]R. L. Banks and Associates, Inc., Development and Evaluation of an Economic Abstraction of Light Density Rail Line Operations, A Report Prepared for the Federal Railroad Administration, Report No. FRA-OE-73-3, Washington, D.C., June, 1973, pp. 22-24.

each type of shipment, origination and termination charges, found in Table 2 of the ICC cost scales, are subtracted from total carload costs. This difference is multiplied by the ratio of miles traveled on company lines to total length of haul. One half of origination and termination charges are added back in where two or more carriers participate in the haul. The formula for determining company share of carload cost appears as

$$a[VC - OTC] + 1/2\ OTC$$

where "a" is the ratio of company miles to total length of haul, VC is system carload variable cost and OTC is system origination and termination cost. If one company completes the entire haul, the full origination and termination cost is included. This procedure provides a 1970 carload cost estimate attributable to the branch. A cost and revenue division factor is formed equal to the proportion of total railroad system cost which is attributable to the line under investigation. An example appears on line 15 of Table 28.

Freight rates obtained from the rate consultant were established for May 1, 1974. Thus, variable cost estimates must be converted from 1970 estimates to 1974 estimates for comparison. Nearly half of variable operating expenses is composed of labor expenditures. Estimates of 1974 variable carload costs are derived by inflating 1970 variable carload costs by the rate of change in average compensation per hour of railroad employees, over the period 1961-1971. Railroad wages have been accelerating. Percent change in railroad wages, $\dot{w}$, as a function of time, t, is

$$\dot{w} = \underset{(0.2845)}{0.7618} + \underset{(0.0345)}{0.8615t}$$

where t = 1 in 1961.[8] Wage growth factors for years 1971, 1972, and 1973 are 9.38, 10.23 and 11.10 percent, respectively. Costs attributable to the line in 1970 are compounded over these three years to provide an estimate of attributable costs at the beginning of 1974. (The compounding factor is 1.0938 x 1.1023 x 1.1110 = 1.3395).

Operating revenue attributable to a branch line from a particular type of shipment is estimated by multiplying total railroad system revenue by the revenue division factor. The realistic assumption made is that ICC rate division procedures are designed to distribute revenues similar to cost distribution. The difference between 1974 revenue and cost estimates is the net annual revenue available to the company, attributable to the subject line.

The final step in determining discounted net present value of continuing line operations entails traffic forecasting and estimation of implied net revenues. The complete traffic forecasting procedure outlined in Chapter IV may be abbreviated when basic traffic data are collected by interviews with local railroad users. Modal split, directional distribution of shipments and route selection are revealed in observable behavior. Traffic forecasting collapses to estimating growth of traffic originations and terminations on the basis of an economic base study.

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[8]This estimator is derived from data contained in Interstate Commerce Commission, Bureau of Accounts, Transport Economics, December, 1972, p. 1, Average Compensation Per Hour (All Time Paid for) Class I Line-Haul Railroads, Years 1961-71.

Two traffic growth situations are assumed. The first assumes a stationary traffic pattern over an indefinite period. A continuous traffic stream is presumed in the image of the 1973 traffic pattern. The second traffic pattern reflects long term population and commercial growth trends discovered in the economic base study. A twenty year investment horizon is assumed for this situation. Outbound grain shipments and receipts of fertilizer and farm machinery are assumed to grow at the same rate as grain production in each county, six percent in Clinton County and three percent in Ionia County. Inbound feed shipments are assumed to decline by one percent annually in Clinton County and to remain stationary in Ionia County, reflecting changes in cattle production. Manufacturing traffic is assumed to continue unchanged. Lumber receipts are assumed to increase at the rate of county population growth, 2.5 percent annually in Clinton County and 0.6 percent per year in Ionia County.

Analysis may be simplified by developing a "discounted growth factor" which reflects both the rate of traffic growth and the opportunity cost of capital. For traffic growth rate g and opportunity cost of capital r over a time horizon of T years, the discounted growth factor becomes

$$F = \sum_{t=1}^{T} \frac{(1+g)^t}{(1+r)^t} .$$

Net revenue in any base year multiplied by this discounted growth factor is equivalent to the present value of net revenue which grows at rate g for T years, discounted at rate r. Assuming a twenty year investment horizon, discounted growth factors for the various commodity groups are shown in Table 29.

Net revenue attributable to a line with a stationary future traffic pattern may be calculated by simply dividing base year net revenue attributable by the opportunity cost of capital. The present value of an indefinite stream of constant net revenues, discounted at rate r, is simply the annual value divided by the discount rate. Net revenue attributable to a line with consideration of traffic growth trends may be estimated by multiplying base year net revenues attributable by the discounted growth factor. Total net revenue over all types of shipments is obtained by summing the present values of net revenue obtained from each type of shipment.

TABLE 29. Discounted Growth Factors for Future Traffic Generations in Clinton and Ionia Counties, Michigan*

Commodity	Clinton			Ionia		
	g	r	F	g	r	F
Grain Fertilizer Machinery	0.06	0.08	16.533	0.03	0.08	12.615
Feed	-0.01	0.08	9.070	0.00	0.08	9.817
Manufacturers	0.00	0.08	9.817	0.00	0.08	9.817
Lumber	0.025	0.08	12.081	0.006	0.08	10.307

*A 20-year investment horizon is assumed.

g = revenue growth rate; r = interest rate; F = Discounted growth factor

Discounted net operating revenues for marginal links and cumulations, for the two example lines, are shown in columns two and four, respectively, of Tables 30 and 31. Estimates in the upper and lower panels reflect stationary and growing traffic trend assumptions, respectively, based upon actual 1973 traffic. Columns three and five of these tables provide estimates of net financial surplus or deficit from continued operation of lines, under the two assumed future traffic patterns.

Net market values of continued operation of the Grand Trunk Western line, shown in Table 30, are particularly illustrative of critical branch lines. Net market value reflects the difference between capitalized value of net operating revenues and the opportunity value of encumbered resources (liquidation values are presented in Tables 26 and 27). A positive market value suggests revenue surpluses above capital costs. A negative value represents the magnitude of subsidy necessary to encourage continued operation.

For the stationary traffic trend, the present value of future net operating income from Ovid to St. Johns is $634,633. This value of income exceeds liquidation value by $499,592. One may say that the station at St. Johns generates sufficient traffic to make continued operation of the St. Johns station profitable. But, the entire line to the St. Johns station must also be profitable to justify continued operation. The present value of net operating income on the entire line from the mainline at Owosso to St. Johns is $1,042,981. This value exceeds what the railroad could make or save by removing the line by $838,760. Since both the St. Johns station is profitable by itself and the entire line leading to St. Johns from the mainline is

TABLE 30. Discounted Net Operating Revenues, Surpluses and Deficits on a Railroad Line: Grand Trunk Western*

Station (Miles)	Marginal Line Net Revenues	Marginal Line Surplus (Deficit)	Cumulative Line Net Revenues	Cumulative Line Surplus (Deficit)
Stationary Traffic Trend (Indefinite Period)				
Ovid (10.0)	$491,570.62	$339,168.79	$ 491,570.62	$ 339,168.70
St. Johns (9.1)	$634,632.87	$499,591.60	$1,042,980.80	$ 838,760.39
Fowler (10.0)	$ 49,886.38	-$102,515.45	$1,092,867.20	$ 736,244.94
Pewamo (5.8)	$ 41,269.75	-$ 34,600.19	$1,134,137.00	$ 701,644.75
Muir (4.6)	$ 51,392.25	-$ 5,318.49	$1,185,529.20	$ 696,326.26
Ionia (8.3)	$589,816.50	$478,838.03	$1,784,345.70	$1,175,164.20
Saranac-Lowell (14.2)	$ 40,475.50	-$196,104.10	$1,824,821.20	$ 979,060.10
Traffic Growth Trend (20-Year Period)				
Ovid (10.0)	$624,943.19	$472,541.36	$ 624,943.19	$ 472,541.36
St. Johns (9.1)	$637,425.00	$502,383.73	$1,262,386.19	$ 974,925.09
Fowler (10.0)	$ 51,490.52	-$100,911.31	$1,313,858.71	$ 874,013.78
Pewamo (5.8)	$ 41,649.43	-$ 34,220.51	$1,355,508.14	$ 839,793.27
Muir (4.6)	$ 51,264.22	-$ 5,446.52	$1,406,772.36	$ 834,346.75
Ionia (8.3)	$590,195.03	$470,216.56	$1,996,967.39	$1,304,563.31
Saranac-Lowell (14.2)	$ 31,787.84	-$204,791.76	$2,028,755.23	$1,099,771.55

*Calculations are based on actual 1973 traffic flows.

TABLE 31. Discounted Net Operating Revenues, Surpluses and Deficits on a Railroad Line: Chesapeake and Ohio*

Station (Miles)	Marginal Line Net Revenues	Marginal Line Surplus (Deficit)	Cumulative Line Net Revenues	Cumulative Line Surplus (Deficit)
Stationary Traffic Trend (Indefinite Period)				
Portland (11.7)	$3,938,911.10	$3,502,833.30	$3,938,911.10	$3,502,833.30
Ionia (15.8)	$3,611,576.50	$3,092,861.40	$7,550,487.60	$6,595,694.70
Traffic Growth Trend (20-Year Period)				
Portland (11.7)	$3,270,269.40	$2,834,191.60	$3,270,269.40	$2,834,191.60
Ionia (15.8)	$2,882,423.40	$2,363,708.30	$6,152,692.80	$5,197,899.90

*Calculations are based on actual 1973 traffic flows.

profitable, the railroad will most likely continue operations to St. Johns without subsidy assistance.

Continuation of the line to Fowler presents quite a different case. Fowler station by itself is an unprofitable enterprise. If the intent of the state or local citizens is to have the railroad terminate at Fowler, a subsidy worth more than $102,500 would be required to cover railroad losses in continued operation. Assuming railroads must pay eight percent interest to attract capital, an annual subsidy payment equal to eight percent of $102,500, or $8,200, would be equivalent. In the case of Fowler station, even though the entire line from the mainline at Owosso to Fowler is profitable, the extra ten miles of line to Fowler causes losses to the company. These losses are visible by noting, in the last column of Table 30, that railroad profits fall from $839,000 to $736,000 by continuing the line to Fowler. The line as a whole is profitable, but the station cannot support itself.

However, a net revenue surplus is generated on the marginal link to Ionia, a distance of 28.7 miles from St. Johns. If revenues accruing to traffic in Ionia, plus whatever revenues can be gained at the intervening stations, more than offset opportunity losses, the three small towns may keep railroad service by merely lying between two larger revenue stations. Liquidation value of a 28.7 mile line segment is estimated at $404,961, excluding land value and tax savings. The city of Ionia alone generates net traffic revenues above this level, under both future traffic assumptions. Revenues generated at intervening stations merely strengthen line viability. Operation between St. Johns and Ionia yields a market surplus of $336,404, or $11,721 per mile, assuming stationary traffic over an indefinite period. With assumed traffic growth and a twenty year investment horizon, operation yields a market surplus of $329,638, or $11,486 per mile. These levels of net receipts are critically low.

Recall that the liquidation value estimator harbors two important inadequacies. First, only market salvage opportunities for roadway resource disposal are considered. Opportunity value, or shadow price, for roadway resources within the firm are not explicitly measured. This fault has no effect as long as market salvage alternatives are greater than internal resource transfer opportunities.

Secondly, the liquidation value estimator excludes the opportunity value of right-of-way property. Land value is excluded due to the unique character it holds in each situation. Property value depends upon the general scarcity of land in the region of the line and upon land use of railroad and adjacent property. Grand Trunk Western property holdings in the city of Ionia run the length of the city and are adjacent to Chesapeake and Ohio properties and trucks. Properties are held on lease by industrial and commercial establishments. If the Grand Trunk Western was to liquidate these properties, land rents to availability of transportation resources would not be affected, as long as the Chessie continues operations to the city.

A 1973 Grand Trunk Western application to abandon a 35 mile line segment from Lakeland to Jackson, Michigan, suggested a net land opportunity value of $700,000, or $20,000 per mile. The line connected eight small towns of a rural region, terminating in a county seat town. An opportunity land value of only half this magnitude would encourage the company to retrieve roadway resources from the Ionia branch line for investment in higher return areas.

Evaluation of the marginal link from Ionia to Saranac is similar to that of links to towns lying between St. Johns and Ionia. Service is continued to Saranac only because the town lies on the line connecting the railroad system to higher revenue stations.

The foregoing abstract evaluation of marginal lines implicitly assumes rerouting of traffic to the west of Lowell. Earlier, rerouting traffic was estimated to entail an added 373,043 car miles annually, based on 1972 traffic volume. Zero cost of rerouting is assumed for three reasons. First, marginal operating labor expense is zero as long as the trip is completed with a single labor shift. Crew expenses typically are indivisible by days. Secondly, engine and car rental expenses are zero for the additional mileage since equipment is already allocated to the train, regardless of which route is chosen. Finally, interline switching expenses are zero for the added mileage, assuming development of joint trackage rights on the Chesapeake and Ohio line. The only added expenditures are in fuel and joint trackage charges.

Evaluation of the Chesapeake and Ohio branch line, in Table 31, reveals a less critical situation. Marginal and total revenue products are substantially above opportunity costs at both the Portland and Ionia stations. Assuming stationary traffic for an indefinite period, opportunity land values and tax savings would have to be $300,000 and $196,000 per mile on links to Portland and Ionia, respectively, to require subsidization.

Illustration of determining the market bound to rail service continuation reveals the unique nature of each line. Line specific land values and extraordinary rehabilitation expenses affect the decision to abandon in a different way for each line. Evaluation of marginal links in relation to adjacent links is necessary to determine the full impact upon railroad net revenues of the abandonment decision. Light traffic stations lying between heavier traffic stations may continue to receive service, where a station of similarly light traffic at the end of a line would not justify continued operation.

Price Discrimination and Collective User Action

The market bound to railroad service provision may be expanded by local freight rate discrimination or collective user action. The revenue enhancement potential of each method is similar. There are two necessary conditions for railroads to be able to ask, or for shippers to offer, a higher price for transport services. First, there must exist a price margin for service between the railroad and the next least costly mode of transport. Secondly, raising of freight rates must not cause firms to close or substantially reduce traffic. A sufficient condition for a revenue enhancement policy to effectively encourage line retention is that the sum of individual firm transport price differentials be greater than or equal to an existing opportunity deficit. In the event the latter condition is not satisfied, user willingness to pay for transportation may at least offset a portion of the deficit, leaving less for non-market consumers to pay.

The procedure used here provides an estimate of maximum potential power of price adjustment policies and private user subsidy to create revenues. Costs of using three alternatives to direct railroad shipment are calculated for each type of shipment originated and terminated in the Clinton-Ionia area. The differences in freight charges between use of railroad and the next least costly alternative is determined for each shipment type, and summed over shipments at each station.

The technique is not equivalent to measuring consumers' surplus. Full consideration is given to the existence of alternative feasible substitutes. Output effects of rate increases are not accounted for, however. Nor is discounting of freight rate differentials for compensating service quality differences allowed. Consequently, estimates must be viewed as maximum potential revenue available, not actual revenues available. This upper limit concept is useful for quick line analysis, yielding an impression of potential sources of line valuation. Where substantial rate margins yield large revenue enhancement potential, further study of price adjustment may be suggested.

The three transportation alternatives include motor carriage, trailer-on-flatcar (TOFC) and movement by railroad to an alternative station with local truck delivery. Truck, TOFC and railroad freight rates were obtained from a rate consultant for each shipment type from the Clinton-Ionia county area. Shipments reflect 1973 traffic; freight rates represent May 1, 1974 prices.

Determination of local private transfer costs from nearby railroad lines to firm storage facilities required engineered estimates. In the cases of bulk fertilizer and lumber, private transfer proved less expensive than commercial delivery. Cost estimates were constructed by interaction with off-line distributors of bulk fertilizer and lumber. Bulk fertilizer is transferred from hopper cars to truck with a portable auger. One hundred-ton carload is equivalent to five truckloads. Including labor, truck charge and auger rental, transfer cost is approximately two dollars per ton. Lumber is transferred to trucks from boxcars by hand at a cost of $400 per carload. For an average 40 ton carload and 1,000 board feet per ton, average added transport cost is approximately one cent per board foot. The transshipment alternative appears very attractive for these very long hauls. Potash is brought nearly 1,500 miles from Sascatchewan; phosphates travel nearly 1,100 miles from Florida; lumber is received from either the West Coast at a distance of 2,400 miles or from the South at a distance of 750 miles. The cost advantage of long distance railroad rates makes local transshipment an alternative superior to trucking.

The second least costly way to ship grain is by truck movement to terminal elevators for further distribution. Total added cost above railroad shipment equals commercial truck rate plus a six cent per bushel unloading fee at terminals less one cent per bushel representing the difference in East Coast railroad rate from the Clinton-Ionia area and from the terminal. Truck rates to the Saginaw terminal elevator were eight cents per bushel from St. Johns and eleven cents per bushel from Ionia. Total added cost of shipping grain by truck to terminals above direct railroad movement is thirteen cents per bushel from Clinton County and sixteen cents per bushel from Ionia County.

Estimates of maximum potential revenue available through price adjustment and collective user subsidy are shown in Table 32 for the example Grand Trunk Western and Chesapeake and Ohio branch lines, under two traffic growth assumptions. For each type of shipment, volume moved is multiplied by the price margin between railroad and next least costly alternative. These results are added over all shipments originating and terminating at a station, to provide an annual flow of revenue enhancement for base year 1973. Present values of a stream of

TABLE 32. Maximum Potential Revenue Enhancement on Two Example Branch Lines*

Station (Miles)	Stationary Traffic Trend		Traffic Growth Trend	
	Marginal Line	Cumulative	Marginal Line	Cumulative
Ovid (10.0)	$ 806,507.13	$ 806,507.13	$1,049,441.00	$1,049,441.00
St. Johns (9.1)	$1,095,861.60	$1,902,368.73	$1,200,888.60	$2,250,329.60
Fowler (10.0)	$ 78,813.80	$1,981,182.53	$ 81,604.15	$2,331,933.75
Pewamo (5.8)	$ 76,058.30	$2,057,240.83	$ 76,758.11	$2,408.691.86
Muir (4.6)	$ 60,000.00	$2,117,240.83	$ 59,628.80	$2,468,320.66
Ionia (8.3)	$1,027,500.00	$3,144,740.83	$1,036,953.00	$3,505,273.66
Saranac-Lowell (14.2)	$ 22,312.50	$3,167,053.33	$ 17,523,34	$3,522,797.00
Portland (11.7)	$ 844,103.37	$ 844,103.37	$ 756,683.97	$ 756,683.97
Ionia (15.8)	$ 441,263.50	$1,285,366.87	$ 378,781.91	$1,135,465.88

*Calculations are based on actual 1973 traffic flows.

annual added revenues are obtained by either discounting a stationary stream of values or by applying the discounted growth factors to individual shipments before summation.

Compare potential private revenue enhancement measures of Table 32 with net market values of Table 30, by marginal link. First note the two marginal links for which service continuation remains beyond the market bound, Grand Trunk Western links to Fowler and Saranac. If each of these marginal links were considered terminal segments of branch lines, freight rate adjustment or collective shipper subsidies would be ineffective in retaining service. Consider Fowler station, for example. Assume the stationary traffic trend. The current value of market deficit on the line segment of ten miles is $102,500. The maximum value of market revenue enhancement is $78,800. Continuation of service to the line would cost the railroad $23,700 plus the opportunity value of land. Service to this line in isolation lies beyond the market bound.

Results of price adjustment may be sufficient, however, to offset opportunity losses incurred by operating marginal links to Pewamo or Muir. Consider the Muir station. Could transportation market participants compensate the railroad company for extending service to terminate at Muir, given that service to Pewamo is justifiable? Again assume an indefinite stream of constant traffic. Potential added revenue from price adjustment or collective user subsidy is $60,000. This more than off-sets the operating deficit of $5,300, excluding land value. If the value of land is no more than $11,891 per line mile, on this 4.6 mile segment, market price adjustment or collective user subsidy is potentially sufficient to encourage continued operation to Muir. Again, this is an abstract example. Existence of heavier traffic at Ionia for which service requires passage through Fowler and Muir, effectively reduces the burden to railroad users in the two smaller towns.

Traffic Consolidation and Diversion

One final consideration necessary for market analysis to reflect regional transportation alternatives is traffic consolidation and diversion. Preceding applications of market bound definitions have abstracted from the complexities of interactions between stations and between railroad companies. Where a town is served by more than one railroad company, shipments may be consolidated on the line of one firm allowing abandonment of the other lines with minor effect to shippers. Continued existence of a railroad alleviates incentives for users to collectively subsidize lines proposed for abandonment. Dampened desires to retain a line in one town diminishes the market bound to continued existence of the line. At the same time, however, increases in traffic on the remaining line strengthen the market value of operations to the remaining company. Traffic consolidation has the potential of converting a condition where two unprofitable lines serve a community, to a situation where one financially viable operation remains.

When abandonment leaves communities without direct service, some customers may be retained. Recall that the best alternative to direct railroad service to farm machinery, bulk fertilizer and lumber dealers is movement by railroad to a nearby community and transfer of materials by truck. When the company abandoning a line continues to maintain the nearest railroad station, traffic may be diverted to another station on the same company's lines. In this situation, associated freight revenues are not lost whether or not abandonment occurs, and are irrelevant to the disinvestment decision. A cost is borne by affected shippers, however, in the magnitude of local transshipment costs. Despite the traffic diversion alternative, shippers will continue to be willing to pay an amount up to the present value of future transshipment costs to discourage the abandonment decision.

Traffic may also be diverted to nearby lines of other railroad companies. Added revenues enhance the market value of these operations. Shippers continue to be willing to pay an amount up to the present value of local transshipment charges. The company considering line abandonment must consider these associated revenues as an opportunity loss for the line abandonment activity.

A final alternative is for firms to either cease exportation or to use nonrail forms of transportation. Under these circumstances shippers are willing to subsidize continued service in an amount equal to the present value of the margin between railroad rates and the cost of the next least costly means of transport. The railroad firm considering disinvestment must consider these losses in revenue as opportunity losses for the abandonment decision. Firms representing other modes gain the net revenue generated from this type of traffic diversion.

Consider analysis of a proposal for the Grand Trunk Western Railroad to abandon the 42.9 mile line segment from St. Johns to Lowell. Assume all traffic originated and terminated in Lowell or to the west may be rerouted at zero cost through Greenville to the north. Assume that all traffic originated and terminated at the stations of Fowler, Muir, Pewamo and Saranac are diverted to their next least costly mode of transport and that all diversions to nearby railroad stations move to the nearest station. Coal shipments are expected to cease where direct railroad service is removed. All Ionia traffic of the Grand Trunk Western is consolidated with Chesapeake and Ohio traffic on the branch line extending from Grand Ledge. All Ionia firms currently using Grand Trunk Western service are located within a few yards of Chessie tracks.

At Fowler, shipments of merchandise, feed and grain are diverted to truck transport. Farm machinery and lumber are diverted to the Grand Trunk Western station at St. Johns. Revenues associated with these latter movements become irrelevant to analysis. Assuming inbound coal shipments cease, all other shippers will be willing to subsidize the railroad in an amount equal to the present value of added transport cost incurred by loss of the railroad.

At Pewamo, farm equipment is diverted to the Chesapeake and Ohio line at Lyons, a station between Portland and Ionia with no current traffic. An unused industrial siding is available for transfer. Bagged fertilizer and grain are diverted to motor carriage.

At Muir, inbound shipments of lumber and bulk fertilizer are diverted to the Chesapeake and Ohio line at Lyons. The two towns are separated by only one mile. The fertilizer blend plant at Muir may find movement of facilities to Lyons a financially sound alternative. Bulk fertilizer distributors have a market radius of about ten miles. Movement of the plant one mile to avoid transshipment expenses would not likely affect the firm's market. Potential revenue enhancement is assumed to be valued at the transshipment cost of two dollars per ton of fertilizer.

At Saranac, feed shipments are diverted to truck transport. Willingness to contribute subsidy funds will be equivalent to the present value of incremental transport charges.

Market evaluation of the entire 42.9 mile abandonment proposal reveals the effects of traffic diversion and consolidation upon the potential market value of a branch line, as shown in Table 33. Net market value based upon current operations and potential market value of the line for the two assumed future traffic patterns are calculated with and without consideration of traffic diversion and consolidation alternatives. Treatment of the line without consideration for traffic diversion or consolidation simulates the value of a line isolated from other railroad facilities. Consideration of facility interactions across companies and across stations provides the more realistic situation in Clinton and Ionia counties.

Market analysis of the abandonment proposal with and without consideration of station and company interactions differs at two points. First, due to diversion of traffic from Fowler to Grand Trunk Western lines at St. Johns, net operating revenues vulnerable to abandonment are reduced when facility interactions are considered. Secondly, consolidation of traffic on the Chesapeake and Ohio line at Ionia removes most of aggregate shipper willingness to subsidize continued service. Potential market value per mile is the sum of net market value in operation and revenue enhancement potential, divided by line length. For the entire proposal, the market bound measure shows a financial surplus of $8,366 and $7,929 per mile for stationary and growing traffic, respectively. If the value of land sales and tax savings per mile is greater than $8,366 per mile, encouragement of the railroad to continue line operations is beyond the power of the market. Effective payment for non-market values is then required to maintain the line.

TABLE 33. Effects of Traffic Diversion and Consolidation on Market Evaluation of a Branch Line: Grand Trunk Western from St. Johns to Lowell, Michigan

Description (Present Values)	Stationary Traffic		Traffic Growth	
	Traffic Diversion Considered	Traffic Diversion Not Considered	Traffic Diversion Considered	Traffic Diversion Not Considered
Liquidation Value Excluding Land	$641,540.58	$641,540.58	$641,540.58	$641,540.58
Net Operating Revenue	$763,262.75	$781,840.38	$746,163.55	$766,387.04
Net Market Value	$121,722.17	$140,299.80	$104,622.97	$124,846.46
Net Market Value Per Mile	$ 2,837.35	$ 3,270.39	$ 2,438.76	$ 2,910.17
Revenue Enhancement Potential	$237,184.60	$1,264,684.60	$235,514.40	$1,272,467.40
Potential Market Value	$358,906.77	$1,404,984.40	$340,137.37	$1,397,313.86
Potential Market Value Per Mile	$ 8,366.13	$ 32,750.22	$ 7,928.61	$ 32,571.42

*Calculations are based on actual 1973 traffic flows.

Summary of Market Valuation Procedures -- A Case

Complete market valuation of a railroad branch line requires both marginal link and complete line analysis. Profitability of a branch line enterprise to a particular station requires that the marginal station generate revenues covering the marginal opportunity cost of maintaining and servicing the associated roadway segment. Secondly, the sum of revenues generated at all stations on the branch must cover total opportunity cost of serving the branch. Table 34 provides estimates of net market value in operation and potential market value for each line segment individually and for cumulations along the Grand Trunk Western line from St. Johns to Lowell, Michigan, assuming stationary future traffic. Critical questions to be answered by market evaluation are three. First, is a subsidy required to maintain branch line services? Secondly, if a subsidy is required, how large a transfer is required to effectively retain service? Finally, can railroad rate adjustments or collective user subsidies generate a transfer of effective magnitude?

Viewing column four of Table 34, only for the Ionia link do operating revenues appear to cover liquidation value on the basis of service rendered at current prices. For other stations, the values of subsidies required to encourage continued service are those shown in column four, to which land sales value must be added. Potential revenue enhancement by market policies of price adjustment or collective user subsidies push potential market values of the Pewamo and Muir stations above zero, evidenced in column seven. However, since potential revenue enhancement estimates are upwardly biased and since liquidation value excludes opportunity land value and the present value of tax savings, market policies

TABLE 34. Market Evaluation of a 42.9 Mile Grand Trunk Western Line From St. Johns to Lowell, Michigan: Stationary Traffic Assumed*

Station (Miles)	Liquidation Value Less Land Value	Net Operating Revenue	Net Market Value	Net Market Value Per Mile	Potential Revenue Enhancement	Potential Market Value	Potential Market Value Per Mile
Marginal Link Valuation							
Fowler (10.0)	$152,401.83	$ 31,308.75	-$121,093.08	-$12,109.31	$ 78,813.80	-$ 42,279.28	-$ 4,227.93
Pewamo (5.8)	$ 75,869.94	$ 41,269.75	-$ 34,600.19	-$ 5,965.55	$ 76,058.30	$ 41,458.11	$ 7,147.95
Muir (4.6)	$ 56,710.74	$ 51,392.25	-$ 5,318.49	-$ 1,156.19	$ 60,000.00	$ 54,681.51	$11,887.28
Ionia (8.3)	$119,978.47	$598,816.50	$478,838.03	$57,691.33	$ 0.00	$478,838.03	$57,691.33
Saranac-Lowell (14.2)	$236,579.60	$ 40,475.50	-$196,104.10	-$13,810.15	$ 22,312.50	-$173,791.60	-$12,238.84
Cumulative Link Valuation							
Fowler (10.0)	$152,401.83	$ 31,308.75	-$121,093.08	-$12,109.31	$ 78,813.80	-$ 42,279.28	-$ 4,227.93
Pewamo (15.8)	$228,271.77	$ 72,578.50	-$155,693.27	-$ 9,854.00	$154,872.10	-$ 821.17	-$ 51.97
Muir (20.4)	$284,982.51	$123,970.75	-$161,011.76	-$ 7,892.73	$214,872.10	$ 53,860.34	$ 2,640.21
Ionia (28.7)	$404,960.98	$722,787.25	$317,826.27	$11,074.09	$214,872.10	$532,698.37	$18,560.92
Saranac-Lowell (42.9)	$641,540.58	$763,262.75	$121,722.17	$ 2,837.35	$237,184.60	$358,906.77	$ 8,366.13

*Calculations are based upon actual 1973 traffic flows.

are unlikely to warrant market provision of service to these two stations, as terminal links.

Calculation of the market bound to provision of railroad service for each link and cumulations, provides decision makers the opportunity to view alternatives of partial abandonment. Assume, for example, that the shippers of Muir are analyzing the viability of terminating the Grand Trunk Western line at Muir instead of at St. Johns. First, the marginal link to Muir must be viable as a distinct entity, after considering traffic diversions and consolidations. Projected current operating revenues fall short of covering liquidation value by $1,156 per mile, but local shippers are willing to pay up to $60,000 in rate hikes or subsidies to maintain service, as seen in the upper panel of Table 34, column five. Potential market value is $11,887 per mile.

Secondly, the entire 20.4 mile segment from St. Johns to Muir must be viable. The lower panel of Table 34 shows that for the entire 20.4 mile line segment, net market value from operations is a loss of $7,893 per mile. Collective willingness of all shippers of Fowler, Pewamo and Muir to pay subsidy to the railroad amounts to $215,000, pushing potential market value to $2,640 per mile. Since the rest of the intervening line is relatively less profitable than the segment to Muir, market value to Muir shippers is diluted over the entire length of the line. The maximum market value of $2,640 per mile is unlikely to cover land value.

The operating deficit to Muir station of $161,000 may be put in perspective with traffic flows. This deficit may be alleviated with a constant annual addition to traffic originations of 50 carloads of grain, a fifty percent increase in grain movements on the line relative to 1973 shipments. The deficit may also be alleviated with a constant annual addition to terminations of 85 carloads of fertilizer, more than a fifty percent increase relative to 1973 shipments.

Effects upon shippers may be seen in the willingness of railroad users to subsidize the line or accept higher freight rates. In Table 34, column six records the sum of present values of increased freight costs to shippers by station and cumulations along the line. Like the values in Table 32, these measures of currently uncounted market value are maximum estimates assuming continued shipment of all commodities except coal, and assuming no shipper discounting for service quality differentials.

Finally, financial value of the Grand Trunk Western abandonment to the Chesapeake and Ohio railroad system can be estimated by calculating net revenue attributable to the line from traffic diverted from Pewamo and Muir and consolidated at Ionia. The Chesapeake and Ohio is a much larger system than the Grand Trunk Western. Consequently, larger proportions of total system net revenues will be attributable to the local line than were previously attributed to Grand Trunk Western lines for similar shipments. Following procedures applied earlier, present value of net operating revenues attributable to the Chesapeake and Ohio line from added traffic are $2.22 million and $2.39 million assuming stationary and growing traffic trends, respectively. Where no institutional constraints prohibit, the Chesapeake and Ohio Railroad could afford a countervailing payment to the Grand Trunk Western Railroad of more than two million dollars to encourage abandonment. This offer would be nearly ten times as great as the offer all users on the line could make to retain service. Thus, barring institutional constraints, the Chessie system could pay the Grand Trunk Western their market value of $317,826 (which would be lower after considering land value and tax savings), and compensate local users for their increased transport costs of $214,872, and still enhance net revenues for the Chessie System in excess of $1.5 million.

Alternative to abandoning the Grand Trunk Western line, is abandonment of the Chesapeake and Ohio line from Portland to Ionia. All railroad traffic served by the Chessie System at Ionia would be shifted to the Grand Trunk Western line leaving no current shippers without rail service. Consequently, no shipper would be willing to pay higher freight rates or provide subsidies to retain the line segment. The Chesapeake and Ohio could make or save $518,715 by abandoning the line, with the forfeiture of $3,611,576 in discounted future net revenues, for a net company loss of over three million dollars, assuming the stationary traffic trend. Gains from land sale and tax savings on this 15.8 mile line segment would have to be nearly $190,000 per mile before the railroad would consider abandonment.

Estimating Non-market Effects

The externality account developed in Chapter V suggests some difficulty in accurately measuring effects of abandonment, outside the market bound. Effects of line closure upon consumer prices have been considered jointly with private collective user subsidies and potential revenue enhancement through market processes. Measurement of abandonment effects upon rental values of land and facilities, upon the environment and upon consumers of options is not attempted. However, empirical measurement tools for effects upon jobs and fuel consumption are introduced with the intent of demonstrating their use. Each tool is designed to measure the magnitude of effects in natural units. Valuation is not prescribed.

Employment Effects

Local job loss was suggested as an imperfect measure of immediate employment effects of line closure, in Chapter V. This measure assumes no capacity of the local economy to absorb laborers, perfect perishability of capital associated with closing firms and is limited to a very narrow geographical perspective. In short, this indicator of job effects serves only to reveal number of individuals temporarily affected by line closure and has no usefulness in directing efficient resource allocation. The technique may be applied to the Clinton-Ionia County area for illustration, however.

Interviews with railroad users revealed that agricultural supply retailers would continue operations with railroad closure. The sensitivity of manufacturing firms to line closure is much more keen. Firms in the two county area which are likely to close without a railroad provide examples of the determinants of employment effects.

Branch plants of national corporations are most sensitive to presence of railroad facilities. Managers at plants of national firms in St. Johns, Ionia and Portland suggested that alternative transport costs would be sufficiently great that rail line closure would precipitate relocation. Capital in plants of national firms is highly mobile. Jobs lost from closure of local plants are likely to be restored upon relocation of similar plants at other locations. Employment effects of this nature are negligible to the entire economy, even though local individuals may suffer unemployment. The loss to the local employee is the gain to an unemployed worker elsewhere.

One of the branch plants in the study region serves one function in the automobile assembly process. This and other facilities contributing to the process have been designed to handle special railroad equipment. Loss of railroad service would break the continuous flow of product in the long-distance assembly line. Maintenance of plant operations of the local facility without the railroad would require investments to modify production processes in all contributing plants.

In another branch plant, the central input to production is a bulk material not currently handled by trucks. Alternative transport would require bagging the bulk material before shipment and unbagging the material before use, at tremendous cost. In addition, the center of comparative advantage, as perceived by the firm, has moved eastward within the state. Line abandonment would cause relocation at another Michigan site. Eventually, even without line closure, the plant would likely move. Abandonment would merely accelerate relocation.

Local jobs affected by firm closings are summarized by station in Table 35. Total number of jobs susceptible to line closure on the Grand Trunk Western line in Clinton County is 701, all of which are in St. Johns. In Ionia County, only two jobs are similarly vulnerable, at Muir, excluding potential employment effects in Ionia. Since Ionia has two railroads, abandonment of one line will not prohibit access to railroad service by firms currently using the line to be removed. Forty-seven jobs are susceptible to line closure on the Chesapeake and Ohio line, in Portland.

TABLE 35. Immediate Local Job Loss Resulting from Railroad Line Abandonments in Clinton and Ionia Counties

Railroad Location Industry	Number of Firms	Jobs Affected (Number)	Railroad Location Industry	Number of Firms	Jobs Affected (Number)
Grand Trunk			Grand Trunk		
Ovid	0	0	Ionia	0*	0*
St. Johns			Saranac	0	0
Manufacturing	2	672	Chesapeake & Ohio		
Retail Lumber	2	29	Eagle	0	0
Fowler	0	0	Portland		
Muir			Manufacturing	1	47
Agricultural Services	1	2	Ionia	0*	0*
Pewamo	0	0			

*Potential job loss is not recorded for Ionia, assuming all firms currently served by the line to be abandoned would be serviced by the remaining railroad.

Every firm which identified itself as vulnerable to abandonment confided that similar operations would be reestablished at locations with transportation facilities including railroad service. Net job loss to the economy may, thereby, be assumed to be roughly zero. The impact upon the local economy may be estimated by the indicator illustrated in Table 35, under proper conditions. However, collective agents with jurisdiction as broad as the state cannot use the illustrated indicator; labor and capital adjustments are likely to replace at least a portion of the jobs lost to abandonment, within the state.

Abandonment and Energy

Computation of added fuel consumption implied by railroad abandonment will be illustrated for the example proposed closure of the Grand Trunk Western line west of St. Johns. Upon line closure, traffic is assumed to move to next least costly modes. Animal feed and machinery are diverted to motor carriage. Outbound grain shipments are trucked to the nearest terminal elevator (Saginaw). Bulk fertilizer and lumber are brought to the nearest station by railroad and delivered to local retailers by truck. Assuming coal users will seek other sources of heating coal, no change in fuel consumption for coal movement was assumed. Finally, all traffic in Ionia is assumed to be serviced by the Chesapeake and Ohio branch line. The procedure for measuring annual added fuel consumption may be followed in Table 36.

The product of shipment distance, load per car and number of cars, obtained from the shipper survey, provides a measure of total railroad ton-miles currently serviced at each station. Ton-miles diverted to motor carriage by each firm is the product of tons shipped and miles

TABLE 36. Effects of Abandonment Upon Annual Fuel Usage: Grand Trunk Western From St. Johns to Lowell, Michigan*

Station	Total Ton-Miles	Added Truck Ton-Miles	Added Truck Fuel (Gallons)	Reduced Railroad Ton-Miles	Reduced Rail-Road Fuel (Gallons)	Annual Net Added Fuel Usage (Gallons)	
						Individual Link	Cumulative
Fowler	1,451,460	202,080	1,981	202,080	594	1,387	1,387
Pewamo	554,460	61,760	605	61,760	182	423	1,810
Muir	2,995,066	840	8	840	2	6	1,816
Ionia	0	0	0	0	0	0	1,816
Saranac	89,250	89,250	875	89,250	262	613	2,429

*Calculations are based upon actual 1973 traffic flows.

hauled by truck. The sum of ton-miles diverted to trucks is summed over all firms to estimate added truck ton-miles at each station. Division of added truck ton-miles by the industry average transportation-energy efficiency ratio of 102 ton-miles per gallon provides an estimate of annual additional fuel consumption by trucks due to abandonment.

Assuming no closing firms and no change in markets, total reduction in railroad ton-miles will equal total addition to truck ton-miles. Division of reduced railroad ton-miles by the industry average transportation-energy efficiency ratio of 340 ton-miles per gallon, serves to estimate annual reductions in railroad fuel usage caused by abandonment.

The difference in annual additions to truck fuel usage and reductions in railroad fuel usage equals the net annual increase in fuel usage implied by the abandonment decision. For the example case, annual net additions to fuel consumption are shown for each station and cumulations of stations in the last two columns of Table 36. The accuracy of these measures suffers from use of industry average transportation-energy efficiency ratios.

Summary

The Clinton-Ionia two-county area has provided examples of numerous, realistic situations under which branch lines must be evaluated. The Chesapeake and Ohio line from Grand Ledge to Ionia currently appears to be a profitable venture. The Grand Trunk Western operation from Owosso to St. Johns appears profitable, as well. However, procedures developed in this investigation suggest that operation beyond St. Johns is provided at an economic loss to the Grand Trunk Western Railroad, assuming diversion of traffic beyond Lowell is possible. Potential revenue enhancement by collective user subsidies is greatly eroded by the ability of shippers to consolidate traffic on the Chesapeake and Ohio line at Ionia and to divert shipments from other towns to remaining Grand Trunk Western stations nearby. While evaluation of external effects of line closure make measurement of the social bound extremely difficult, several impact indicators have been developed which will assist decision makers in resolving "border line" subsidization decisions.

Many elements of the evaluation procedure remain rather crude and require further investigation for refinement. Also critical is the fact that statistical properties of the estimators of subsidy required and willingness to pay subsidy are unknown. These problems and others leave the subject of branch line evaluation rich with research potential. Research issues are considered in the next chapter.

CHAPTER VII

CONCLUSIONS FOR POLICY PLANNING AND RECOMMENDED RESEARCH EXTENSIONS

The foregoing chapters contain basic railroad freight transportation market characteristics, criteria for market and social investment and disinvestment in railroad branch lines and a procedure for evaluating variables composing investment criteria. Conclusions are drawn together here to relate research findings to improved transportation policy planning processes. Conclusions are followed by a summary of related issues which remain unresolved. A portion of these issues involves expansion of models developed in this research; a portion also involves complementary elements of transportation policy not considered in this project.

Conclusions for Policy Planning

Railroad firms may be described best as producers of multiple outputs. Multiple product production implies inherent competition among outputs for durable plant and rolling stock resources. Ability to transfer durable resources readily between products fosters a heightened sensitivity of output to market signals, relative to single product producers. The more sensitive production is to market signals, the stronger and more complete must be policy tools designed to balance economic forces at output levels which deviate from those predicted by unconstrained market equilibria.

Profit maximizing railroad firms, unconstrained by regulatory policy, will move to disinvest in branch line roadway when the discounted net present value of future operating revenues falls below liquidation value of the line. Consideration of roadway capacity adjustment opportunities has revealed a broad range of incremental salvage and acquisition activities by which to respond to changes in market demand signals. However, roadway capacity salvage opportunities reach their minimum at a considerable level of salvage value. In the example two-county case study, line liquidation value averaged approximately $15,000 per mile on the Grand Trunk Western line and nearly $33,000 per mile on the Chesapeake and Ohio line, excluding land salvage value. The branch line disinvestment criterion suggests that when the present value of net operating revenues falls below liquidation value, the railroad experiences economic losses.

Review of thirty-two applications to abandon railroad lines in Michigan during 1969-1972, reveals that railroads tend to operate branch lines until accounting losses are incurred, before seeking abandonment of the line. Whether or not the data is completely accurate is unimportant. That railroads perceive the necessity to show net operating losses before submitting abandonment applications suggests an effective policy encouraging an investment level consistent with a constrained policy equilibrium which deviates from unconstrained market equilibrium. While unconstrained firm equilibrium implies disinvestment when the value of the line in service falls below value of the line in salvage, the policy constrained equilibrium suggests disinvestment only when value of the line in operation falls to zero.

Reputed conduct of railroad firms may be explained by this deviation of policy objectives from market equilibrium. Railroads are often accused of purposely discouraging traffic on light density lines in an effort to create a financial position warranting abandonment. This conduct appears as rational behavior by profit maximizing railroad firms with positive discounted net earnings prospects which lie below salvage value of the line. Traffic discouragement behavior of railroads may be expected as a means to turn economic losses to accounting losses to meet administered disinvestment criteria.

This conclusion suggests one of two courses of remedial action to adjust conventional abandonment policy. If the regulatory authority adopts the notion that the cost of risk associated with traffic deterioration is part of the price of a corporate charter with special grants of privilege by the people, a more effective policy of service maintenance must be enforced to control traffic discouragement behavior in response to market forces. A second course would be for the regulatory authority to recognize opportunity cost, rather than accounting cost, as the basis for allocation of railroad resources. The latter would bring policy and firm objectives into harmony and the enforcement function would be unnecessary.

Local price discrimination policy by railroads and local private collective subsidy activity bears revenue enhancement potential which may be sufficient to encourage line retention in some communities. A question which remains unresolved is that posed by Stigler in response to Mrs. Robinson's recommendation to employ price discrimination to justify production in decreasing cost industries. The question involves the impact of differential pricing of local railroad services upon allocative efficiency among all modes in the regional transportation industry. Railroads have complained for decades that implicit subsidization of other modes has posed a major barrier to financial development of railroading. To turn the tide and subsidize railroading appears to have no more foundation. General regional equilibrium modeling for integrated transportation planning may be necessary to find optimum public investment in transportation systems.

Estimators of railroad freight service demand remain in a developmental stage. Strong statements of conclusion are not warranted. However, demand studies of Chapter IV provide evidence suggesting some influence of service quality of own and competing modes upon level of railroad service demanded and upon modal split. If further demand estimation with independent data samples verifies results of Chapter IV, such information will be useful in policy making in at least two respects. First, this information would provide estimates of reduced service use with service quality deterioration. Currently, shippers suggest that service quality deterioration causes major reductions in service demand. Preliminary estimates based on available sample data show only slight quality elasticities of demand for railroad service. Estimation may serve as a basis of service quality regulation as well as rate regulation.

Secondly, empirical estimates of demand response to service quality variation would serve to aid transportation planning. Profit maximizing railroad firms could more finely tune service levels to use equipment and personnel more efficiently. States and local transportation authorities could use quality-demand information to select optimum service quality levels to bargain for in subsidy contracts.

Evidence presented in Chapter IV suggests that importance of individual service quality characteristics differs between commodities.

Consequently, measurement of demand response to service quality will require major efforts in estimation activity.

Results of Chapters V and VI reveal that external effects of line closure may spread far beyond local communities being abandoned. External costs appear largely concentrated in the local community while external benefits largely accrue to communities outside the local area. Adjustment of labor and capital resources to line closure may cover a broad area. For subsidies to represent efficient resource allocation, the subsidizing authority must have broad jurisdictional bounds. The state level of authority is likely sufficient.

An authority with narrower bounds may tend to evaluate lines in isolation from other transportation facilities in the broader region, ignoring potentials for traffic diversion and consolidation with other facilities continuing service. This may lead to underestimation of subsidy required and overestimation of community willingness to subsidize, frustrating the policy process. This occurs when a portion of line revenues is retained by the abandoning railroad with service from other stations and when a portion of current railroad users may be unaffected by line closure due to continued service by other companies.

The procedure for branch line evaluation, demonstrated in Chapter VI, may be used to address the immediate concern of determining whether or not to subsidize a line. The single case, provided in this volume, demonstrates the unique nature of each branch line. Each line has unique characteristics of land value, rehabilitation expenses and joint trackage contracts which force the subsidy decision to be investigated on a line by line basis. Line by line evaluation does not imply investigation of roadway segments in isolation of one another. Each line must be considered in the context of all revenue centers on the line, proximity of other railroad facilities and the network of all weather highways in the region. The regional transportation system is then viewed with and without the subject line to make the subsidy determination.

Estimators of subsidy and willingness to subsidize suffer from lack of known statistical properties. Since the variance of a sum is the sum of individual variances, an estimator composed by many steps in calculation, with less than perfect data sources, is likely to have a very large variance. As a result, confidence in resulting estimates must be conservative at best. Importance of the accuracy of estimates is directly related to the cost of making wrong judgments. Where the cost to communities of abandoning a line which will generate sufficient revenues in the future is extremely high relative to the cost of annual subsidization of a line destined to be unused, a community may be willing to pay the subsidy as insurance of transportation facilities for unknown future developments. Where priorities for community resource expenditures rest with solution of current problems, the community may not be willing to subsidize the line, even though the evaluation procedure does not provide great confidence. An added policy decision must be considered, then. To what degree is the community willing to subsidize the railroad as insurance against making a wrong judgment on the basis of approximate information?

Recommended Research Extensions

Research reported in this volume has revealed numerous topics for continued research relating to railroad branch line abandonment. Many recommendations entail expansion and refinement of models and techniques developed in this investigation. Other recommendations concern topics tangential to the current study, but useful to overall branch line analysis.

The railroad firm investment planning model, developed in Chapter III, must be expanded to provide application to larger roadway plant adjustments. Use of the model by railroads and planning agencies to evaluate package abandonment programs and other major system adjustments, requires refinement of the gain function to reflect the interaction between rolling stock and roadway plant. Where major roadway plant adjustments are considered, implied adjustments in power and movement units may activate equipment acquisition and salvage activities. Consideration of these interactions is important to accurately determine the magnitude of subsidy required to encourage retention of service. Expansion of the railroad investment planning model must include explicit attention to the functional relationship between roadway expanse and equipment stock, and explicit accounting of a broad range of equipment and roadway capacity acquisition and salvage prices.

Fine tuning of the railroad investment planning model also requires research on cost relationships specific to branch line enterprises. Currently, regional railroad system cost averaging, reported as Rail Form A by the Interstate Commerce Commission, serves as the basis of cost information. Proposed rules for branch line subsidy calculation call for evaluation of off-branch costs at a magnitude of system average costs. As noted in Chapter III, the relevant branch line marginal costs, which are brought into line with marginal revenue product, vary as the output unit assumes different definitions and are quite dependent upon rate of utilization of equipment and roadway resources. The research questions which arise are two. What are the empirical nature and magnitude of on-branch marginal costs of operating specific branch line enterprise units? Secondly, what are the empirical nature and magnitude of off-branch marginal costs of servicing traffic to and from specific branch line enterprise units? Information with which to make these empirical determinations may be difficult to obtain. Researchers may be forced to engineer cost estimates with the cooperation of railroad operations and accounting personnel.

Further development of quality-demand and modal selection probability models requires more academic investigation before seeking parameter estimates. Models may be tested with independent data sources to check consistency of performance of the semilogarithmic functional form of demand estimation. New data may then be used to develop estimates of quality-of-service demand elasticities and cross-elasticities. The value of this research will be improvement of ability to optimize service levels for which to contract and subsidize, making the subsidy activity a more efficient and effective activity. Developing models which isolate quality of service factors will also provide a better view of price and cross-price elasticities of demand for each mode. This knowledge may assist rate regulators in building rate policies which are more in tune with actual market conditions and promote resource efficiency.

Refinements of social impact indicators of community transportation adjustments may have high payoff in developing public investment policy consistent with allocative efficiency. Research is needed to operationalize these indicators as measures of demand for "existence" of transportation facilities. Operationalizing these indicators must encompass both measurement of external effects of adjustments and associated valuation procedures. Development of some magnitude indicators will require joint efforts between engineers and economists. Temporal distribution of impact flows should be studied to distinguish ephemeral from lasting effects of transportation system adjustments. Impact flows then are to be implicitly discounted whether described in monetary or nonmonetary units.

Valuation of external effects of transportation adjustments provides the normative content of prices and social value weights. Development of standard operating procedures for valuing external effects may be approached with a series of multiple objective project evaluations performed in association with local or state decision makers. During the next few months, the communities of Michigan will provide a laboratory for abandonment decision making as local groups respond to the provisions of the Regional Rail Reorganization Act.

Alternatives to subsidization also provide ground for fruitful investigation. Federal subsidy procedures are intended as a temporary measure to ease local community adjustment to line closure. Longer term solutions may prove suitable as means to maintain local railroad services. Feasibility analysis of various institutional mechanisms for retaining roadway under anticipated traffic and cost conditions will be useful. Local ownership and operation of branch lines as short-line railroads, cooperative transportation associations which generate and schedule traffic, and state ownership of roadway are just three alternatives to be studied.

Finally, modeling of small, regional transportation systems is recommended to observe interaction between modes. Determining optimum public investment in rail roadway in the context of all existing and alternatively proposed modal services provides planning with sensitivity to technological and behavioral complementarity and substitutability of modes.

Small-region system modeling is also required to resolve the Stigler-Robinson debate on whether differential pricing or subsidy among modes creates a disequilibrium condition for other modes. Discussion of differential government subsidization of modes, by means of transportation facility investment, has been largely conjectural to this point. Theoretical development of optimal public investment in a general equilibrium context and empirical development measuring effects of subsidization upon local transportation systems will be valued highly in transportation planning.

APPENDIX

APPENDIX A

The Michigan Freight Transportation Survey

MICHIGAN FREIGHT TRANSPORTATION SURVEY

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

The purposes of this freight transportation survey are: 1) to understand the quantity and nature of freight movements originating and terminating in Michigan, and 2) to provide an opportunity for individual users of transport services to candidly communicate their concerns on quality of transport service and their future transportation requirements. Information obtained by this survey will be used in a broad-based, multi-modal transportation system planning effort.

Information received will be held in complete confidence and will be converted to an anonymous data file immediately upon receipt. Publicly reported results will be in summary form, not revealing the identity of individual respondents. Some of the following questions will require reference to your 1973 business records. Please answer each question as completely and accurately as possible. If you lack the information for complete answers, return the questionnaire with the information available; it will still be useful. Use extra sheets if spaces provided are insufficient.

We would appreciate your participation in planning your transportation system.

Director

John P. Woodford

I. INBOUND SHIPMENTS OF SUPPLIES

A. In the spaces below, please provide the requested information for inbound shipments made during 1973. Combine deliveries of the same product from the same place of origin as one entry. Treat different products and different origins as separate entries. If detailed information is not available, please indicate totals for all inbound shipment.

1. type of supply material received (such as lumber, metal cans),
2. place of origin (city name is most helpful, state name is acceptable),
3. freight charges on 1973 shipments,
4. tons received in 1973,
5. number of days in transit for the typical shipment (shipping date to receipt date),
6. number of loads received in 1973.

TRUCK

1. Material (name)	2. Origin (city/state)	3. Freight Charges ($)	4. Tons Received	5. Transit Time (days)	6. Number Truck-loads (1973)
Total for 1973					

RAILROAD

1. Material (name)	2. Origin (city/state)	3. Freight Charges ($)	4.Tons Received	5. Transit Time (days)	6. Number Car-loads (1973)
Total for 1973					

WATER

1. Material (name)	2. Origin (city/state)	3. Freight Charges ($)	4. Tons Received	5. Transit Time (days)	6. Number Boat-loads (1973)
Total for 1973					

B. Are supplies received at a constant rate throughout the year . . .

1. by truck? ☐ Yes; ☐ No. If No, peak months are ______________ .
2. by rail? ☐ Yes; ☐ No. If No, peak months are ______________ .
3. by water? ☐ Yes; ☐ No. If No, peak months are ______________ .
4. What percent of inbound shipments come in during peak months? __________ %

C. If all inbound shipments were stopped, how many days could you operate from stored inventories? __________ days.

D. Of $1,000 worth of supply shipments ordered, what is the average value of damage and loss due to shipment

by truck? $ ______________ by rail? $ ______________

E. For $1,000 worth of supply shipments ordered, what is the average cost of transportation

by truck? $ ______________ by rail? $ ______________

II. OUTBOUND SHIPMENTS OF PRODUCTS

A. In the spaces below, please provide the requested information for outbound shipments made during 1973. Combine shipments of the same product to the same destination as one entry. Treat different products and different destinations as separate entries. If detailed information is not available, please indicate totals for all outbound shipments.

1. type of product commodities shipped,
2. place of destination,
3. freight charges on 1973 shipments,
4. tons shipped in 1973,
5. number of days in transit for the typical shipment,
6. number of loads shipped in 1973.

TRUCK

1. Material (name)	2. Destination (city/state)	3. Freight Charges ($)	4. Tons Shipped	5. Transit Time (days)	6. Number Truck-loads (1973)
Total for 1973					

RAILROAD

1. Material (name)	2. Destination (city/state)	3. Freight Charges ($)	4. Tons Shipped	5. Transit Time (days)	6. Number Car-loads (1973)
Total for 1973					

WATER

1. Material (name)	2. Destination (city/state)	3. Freight Charges ($)	4. Tons Shipped	5. Transit Time (days)	6. Number Boat-loads (1973)
Total for 1973					

B. Are outbound product shipments made at a constant rate throughout the year . . .

1. by truck? ☐ Yes; ☐ No. If No, peak months are ______________.
2. by rail? ☐ Yes; ☐ No. If No, peak months are ______________.
3. by water? ☐ Yes; ☐ No. If No, peak months are ______________.
4. What percent of outbound shipments go out during peak months? __________ %

C. What is the shortest, longest, and average period of delay in receiving for-hire trucks and railroad cars? (number of days delivery occurs after the date specified in the equipment order; use spaces below).

TRUCK

1. ________ days is shortest.
2. ________ days is longest.
3. ________ days is average.

RAILROAD

1. ________ days is shortest.
2. ________ days is longest.
3. ________ days is average.

D. Of $1,000 worth of products shipped, what is the average value of damage and loss due to shipment

by truck? $ ______________ by rail? $ ______________

E. How many times were you contacted by a carrier sales representative in 1973, by letter, telephone, or personal visit?
1. trucking service sales representative ____________.
2. railroad service sales representative ____________.

F. Were some shipments made by truck during 1973 because rail cars or other services were not available?
1. Tons of shipments affected ____________.
2. Truck freight paid $ ____________.
3. What would rail charges have been on this quantity? $ ____________.

G. For $1,000 worth of products shipped, what is the average cost of transportation

by truck? $ ____________ by rail? $ ____________

III. YOUR COMPANY

A. How many fulltime employees work at this plant? ____________.

B. How many man-months of part-time help will you hire in a typical year? ____________.

C. Describe the overall trend of transportation usage, by your business, at this location during the past 3 years:
☐ Increasing truck and Increasing rail use. ☐ Increasing truck and Decreasing rail use.
☐ Decreasing truck and Increasing rail use. ☐ Decreasing truck and Decreasing rail use.
☐ No change.

D. Do you own trucks for use in the business (excluding pick-up trucks)? ☐ Yes; ☐ No.

E. Do you own or lease rail cars currently? ☐ Yes: ☐ No.

F. Do you have rail cars on order for purchase or long-term lease? ☐ Yes; ☐ No.

G. Over the next 3 years, do you expect your business output of products and services at this location to
☐ expand? By what percent annually? ____________%
☐ contract? By what percent annually? ____________%
☐ remain about the same as now?

Explain change: ____________

H. By which carrier companies are you served?
Trucking companies ____________ Rail Companies ____________
Water Companies ____________

I. How would you characterize your dependence on rail service?
☐ We don't use the railroad.
☐ The railroad offers a competitive alternative with trucks, but the business would not be harshly affected by loss of rail service.
☐ Loss of the railroad would cause our transport expenses to increase substantially.
☐ The plant would close if rail service was discontinued.

J. Please record other transportation concerns which you have: ____________

Company Name ____________

City of Location ____________

Thank You For Your Help

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