MONTANA STATE UNIVERSITY

The Effect of branch line abandonment on local highways : a site specific study
by Thomas Randall Fortenbery

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Applied Economics
Montana State University
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Abstract:
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The methods were then applied to a study site, the Newlon Junction to Richey branch line, and the estimated highway costs associated with the abandonment of this line were computed. The estimated highway costs were then used to show that exclusion of these costs in a benefit-cost analysis of branch line abandonment will affect results. From this it is proposed that any analysis which excludes highway impact is incomplete, and as such the results do not suggest an optimal level of rail activity.

The conclusion drawn from a review of the literature is that previous studies of branch line abandonment have not been complete. They have not explicitly considered highway impact in the analysis. As such, they have not accurately estimated the impact of branch line abandonment on local communities.

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of

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MONTANA STATE UNIVERSITY
Bozeman, Montana

June 1984

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ABSTRACT

A method to estimate physical highway impacts resulting from branch line abandonment was developed. Next, incremental cost curves were derived which show the incremental costs associated with increased truck traffic.

The methods were then applied to a study site, the Newlon Junction to Richey branch line, and the estimated highway costs associated with the abandonment of this line were computed. The estimated highway costs were then used to show that exclusion of these costs in a benefit-cost analysis of branch line abandonment will affect results. From this it is proposed that any analysis which excludes highway impact is incomplete, and as such the results do not suggest an optimal level of rail activity.

The conclusion drawn from a review of the literature is that previous studies of branch line abandonment have not been complete. They have not explicitly considered highway impact in the analysis. As such, they have not accurately estimated the impact of branch line abandonment on local communities.

CHAPTER I

INTRODUCTION

A recent occurrence in Montana has been a shift from rail transportation services to trucking services in the short haul transport of grain from rural areas to assembly centers. One cause has been the abandonment of railroad branch lines which the railroad companies assert are not economically viable without subsidization from other revenue sources.

The passage of the Staggers Rail Act of 1980 and Interstate Commerce Commission (ICC) Decision Ex Parte 347 (sub. no. 1) are institutional changes which will affect the behavior of railroads in terms of branch line abandonment. It has been suggested that the result of these actions will be an environment in which branch line abandonment may be less costly and time consuming for railroads (Seaver, 1983). It has also been suggested by the Montana Governor's Transportation Advisory Council that the combination of the Staggers Act and Burlington Northern's (BN) increased usage of high volume unit trains and large grain subterminals may result in an accelerated level of branch line abandonment in Montana. One result could be an increased number of Montana grain producers being isolated from local rail service (Governor's Transportation Advisory Council).

The transition from rail to truck for short haul services has not been accomplished without protest from some affected communities. There is concern that much of the adverse economic impact of railroad abandonment accrues to rural communities; elevators lose business, farmers face longer truck hauls from the farm, local tax bases decrease, and the rate of road deterioration increases.

Railroads have argued that the utilization of unit trains and subterminal facilities will result in reduced rail rates for farmers. It has been countered, however, that the lower

freight rates may not be sufficient to offset the increase in trucking costs from farms to mainline facilities. Wheat farmers argue that loss of local rail service will jeopardize their ability to profitably market their produce. In addition, rural communities fear that loss of local rail service could adversely affect local businesses. If farmers must travel to mainline communities to acquire rail service, they may also rely on mainline communities for other services previously purchased locally.

The controversy surrounding branch line abandonment to date has been lacking in analytical inputs. The result has been confusion by shippers, carriers, and governments concerning the local effects of branch line abandonment. The few analytical studies which have been done have not explicitly considered highway impact in the analysis. Highway impact has either been assumed minimal or has not been discussed. Therefore, this study will discuss a method to calculate highway impact resulting from branch line abandonment, and thus provide the basis for a more comprehensive understanding of the community impacts of branch line abandonment.

The Montana Rail System

In 1983 there were 5,126 miles of rail track operating in the State of Montana (Montana Rail Plan, 1982). The BN operated 93 percent (4,769 miles) of this total, and the Union Pacific, Soo Line, and Butte, Anaconda, Pacific Railroad operated the remaining 7 percent (Montana Rail Plan, 1982). The BN also operated 18 branch lines in Montana in 1983. Thirteen of these, totaling 319 miles, were in some category of proposed abandonment (Lewis).

There are three categories identified by the State of Montana in the abandonment process. Category one contains those lines the railroad anticipates filing for abandonment within three years (Montana Rail Plan, 1980). There were ten Montana branch lines in category one in 1983. They totaled 160.5 miles of track (Lewis). Category two refers to

those lines which the carrier is studying for possible abandonment because of an expectation that either operating costs or rehabilitation costs will be excessive compared to potential revenues (Montana Rail Plan, 1980). In 1983 there were no Montana lines classified in category two (Lewis). Category three refers to those lines for which an application for abandonment has been filed with the ICC (Montana Rail Plan, 1980). There were three branch lines statewide totaling 158.5 miles included in category three in 1983 (Lewis).

Statement of the Problem

The Newlon Junction to Richey branch line extends 45.4 miles through Richland and Dawson Counties in Eastern Montana. There are three active stations along the line (Lambert, Enid, and Richey) which primarily handle farm products (93 percent of all traffic and 100 percent of outbound traffic in 1980). Seventy-three percent of the traffic was accounted for by three shippers/receivers in Richey, while five additional customers accounted for the remaining 27 percent (Montana Rail Plan, 1982). Traffic volume on the line fluctuated considerably in the late 1970s and by 1980 was down measurably from the previous years (Table 1). The line averaged 7.5 carloads per week in 1980, and generated a total revenue for BN of about $1.3 million (Table 1), with an estimated net profit of $172,000 (Montana Rail Plan, 1982). As noted in Table 2, the total avoidable costs incurred by BN from providing branch line service was a little over $1 million. In addition, the opportunity cost foregone based on a 12.1 percent rate of return on the line amounted to $48,957 (Montana Rail Plan, 1982).

In 1983 the Newlon Junction to Richey line was in category one of abandonment. The 1982 Montana Rail Plan identified the line as being in poor condition with service sometimes interrupted in wet weather due to the poor condition of the road bed. The Rail

Table 1. Railroad Use Statistics for the Newlon Junction to Richey Branch Line in 1980.

Station	Carloads Number	Carloads Percent	Tons Number	Tons Percent	Commodity
			Originating		
Lambert	74	19.0	6,377	19.1	Farm Products
Enid	21	5.4	1,810	5.4	Farm Products
Richey	267	68.6	23,008	68.8	Farm Products
			Terminating		
Lambert	10	2.3	885	2.6	Chemicals
Richey	13	3.4	1,151	3.4	Chemicals
	3	1.0	150	0.5	Lumber & Wood Products
	1	0.3	50	0.2	Other
Total Traffic	389	100.0	33,431	100.0	

1980 Statistical Summary

Length: 45.4 miles
Million Gross Ton-Miles Per Mile: 0.086
Carloads Per Week: 7.5
Carloads Per Mile: 8.6
Revenue: $1,301,126

Traffic Volume History

1976	801
1977	450
1978	649
1979	865
1980	389

Source: 1982 Montana Rail Plan, Montana Department of Commerce.

Plan also identified the estimated rehabilitation cost of the line to be at $5.1 million. Without rehabilitation the line will be incapable of handling fully-loaded (100 ton) covered hopper cars in the future (Montana Rail Plan, 1982).

Freight traffic on the Newlon Junction to Richey line currently faces competition from truck services and unit train facilities in Sidney, Circle, and Wolf Point (see Figure 1). The branch line is paralleled from Sidney to Richey by Federal Aid Primary 51 (State Highway 200) which also continues west to Circle. Federal Aid Secondary 254 connects Richey with Federal Aid Primary 25 allowing travel northwest to Wolf Point, and Glendive

Table 2. Estimated Revenues and Costs for the Newlon Junction to Richey Branch Line in 1980.

Revenues Attributable	Revenues/Costs
1. Freight Originated and/or Terminated on Branch	$1,301,126
Avoidable Costs	
2. On-Branch Costs (Lines 2a through 2c)	$ 468,928
a. Maintenance of Way and Structure (Normalized)	362,701
b. Transportation	77,134
c. Freight Car Costs	29,093
3. Off-Branch Costs	612,000
4. Total Avoidable Costs (Line 2 plus Line 3)	$1,080,928
5. Avoidable Loss from Operations (Line 1 minus Line 4)	($ 220,198)*
6. Net Liquidation (Line 6a plus Line 6b)	$ 404,600
a. Materials	211,600
b. Land	193,000
7. Rate of Return	12.1%
8. Opportunity Cost Foregone (Line 6 times Line 7)	48,957
9. Total Avoidable Loss (Line 5 plus Line 8)	($ 172,241)*

*Parenthesis indicates gain.
Source: 1982 Montana Rail Plan, Montana Department of Commerce.

to the southeast. Figure 2 shows the Newlon Junction line and local roadways, including the Montana Highway Department's estimates of highway traffic density in 1981.

An expected result of abandonment of this line is an increase in grain traffic over the local highway system in order to market locally produced grain. This, in turn, may adversely affect the quality of the road system in the Richey area. The problem, then, is to determine if abandonment of the Newlon Junction to Richey branch line would adversely affect the existing road system, and then identify the costs associated with any highway impact.

Need for the Project

There has been little research quantifying the various impacts of branch line abandonment on individual communities. Such work may be desirable, however. For example, the importance of quantifying the economic impact of rail line abandonment is evident in the

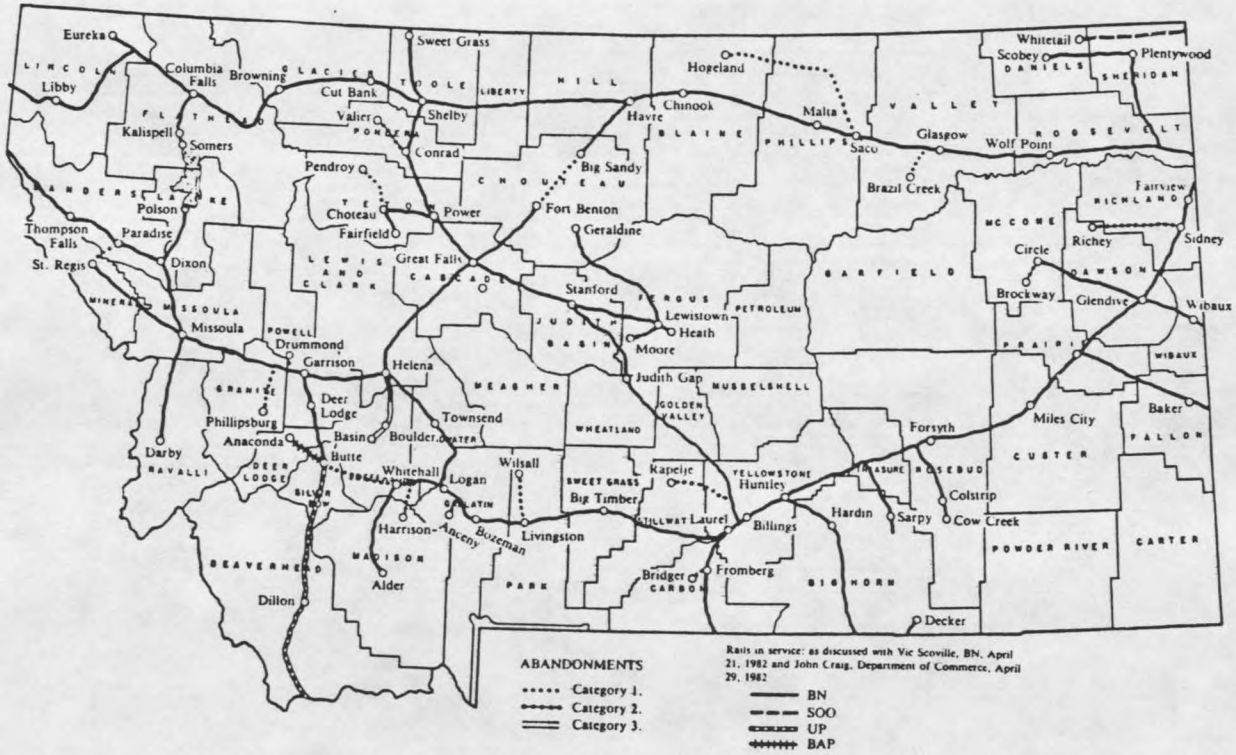

Figure 1. The Montana Railroad System, 1982.

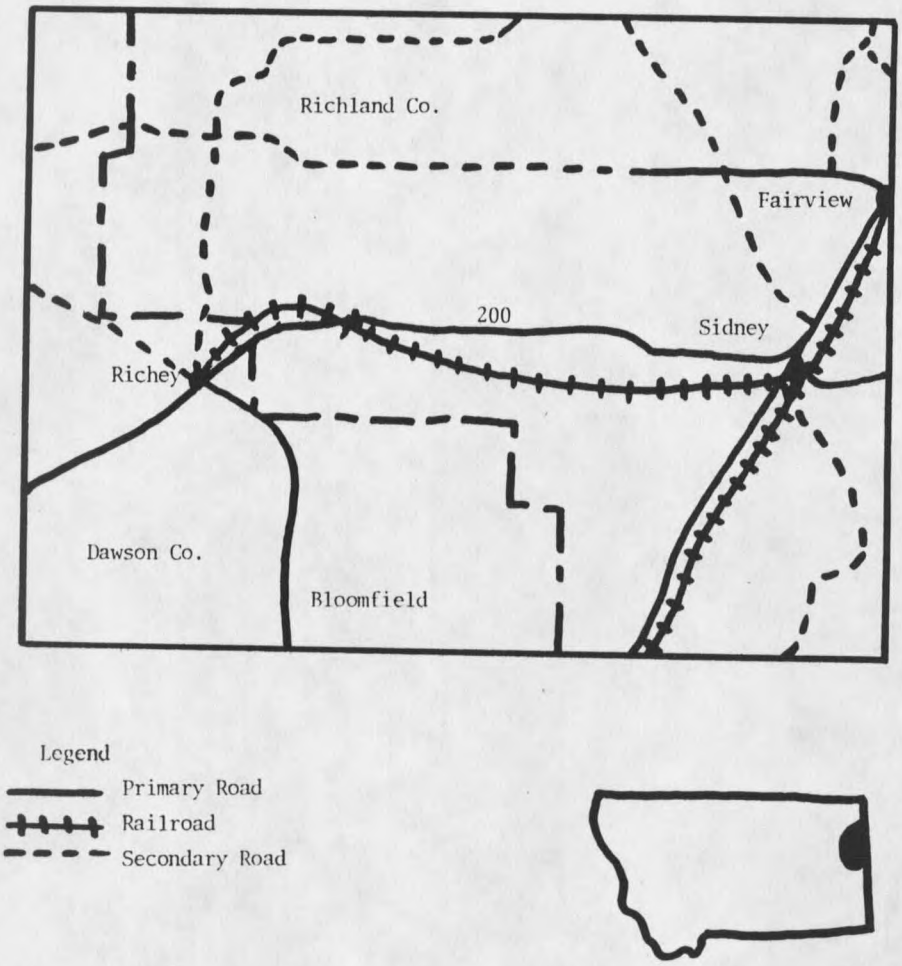

Figure 2. The Newlon Junction to Richey branch line.

lack of consensus among affected parties as to the magnitude of various impacts. Conceivably, improved information could reduce conflicts and possibly prevent litigation in some cases.

Of specific interest is the impact on local road systems. This is because Montana's road systems provide the only alternative to rail systems in grain marketing. Unfortunately, however, there is no consensus as to the effect a branch line abandonment will have on a local road system. Purnell (1976) contends that an abandonment will usually adversely affect local road systems, while Zimmer (personal communication) states that there has been little work or agreement (in the engineering profession) in identifying the best way of measuring the impact.

The Newlon Junction to Richey branch line was chosen to study potential highway impacts in Montana for five reasons. First, the line seems to be typical of lines being considered for abandonment in Montana. It is currently classified in category one of abandonment, as are the majority of branch lines in Montana. This implies that there has not been a decision made regarding abandonment of the line. Second, the line predominantly serves the agricultural industry, again typical of Montana lines considered for abandonment. Third, there is potential competition from both trucks and truck/unit train combinations for branch line freight. Fourth, there are few alternate truck routes to substitute for branch line service. Fifth, data exist that reflect the traffic patterns on the single primary road serving the area. This will allow estimates of the amount and distribution of freight traffic diverted from the branch line to the highway, and subsequently the impact of such a diversion,

Objectives

This study has two main objectives. The first is to present a method for quantifying the highway impacts resulting from branch line abandonment. This method will then be applied to the Newlon Junction to Richey study site. This will provide an estimate of the

physical and corresponding economic impact on Montana Highway 200 which would result from rail abandonment.

The second objective is to discuss why calculation of highway impact is important in considering the overall effect of an abandonment on a community. If highway impacts are not explicitly identified, then it is possible that the costs to a community resulting from branch line abandonment will be underestimated. The result in such a situation would be a less than comprehensive understanding of the social costs resulting from branch line abandonment.

Procedure

The first step requires that data reflecting the total amount of grain and other freight shipped over the Newlon Junction to Richey branch line on an annual basis be generated. This is important in that it will provide a basis from which to estimate the expected increase in highway freight traffic resulting from abandonment, The annual rail traffic will be estimated using rail traffic data from 1976 to 1982. It is useful to consider rail traffic over several years because of annual fluctuations in traffic (Table 1).

The estimated increase in highway freight traffic will then be divided into equivalent axle loads (EAL).[1] The estimated increase in EAL's will be compared to the current traffic density estimates for Highway 200 from the Montana Department of Highway's "Rural Traffic Flow Map." From this comparison an estimate of the expected range of percentage increases in EAL's resulting from abandonment can be calculated. The percentage increase in EAL's can then be used to estimate highway damage by use of a damage function.

[1] Equivalent axle load is a standardized measure of the total traffic moving across a road surface in some given time period. It involves expressing the gross weights of all vehicles in terms of eighteen thousand pound axle loads.

A damage function expresses the increased pavement thickness required to maintain road serviceability at pre-abandonment levels. The damage function corresponding to the Richey area will be derived by plotting points associated with pavement increases for every 10 percent increase in traffic loads. The equations used to derive these specific points have been presented by Purnell (1976), and are discussed in Chapter 3.

Once a damage function has been specified, an incremental cost curve can be derived which will show the expected highway damage cost associated with any given level of highway traffic increase. From the cost curve the increased costs of highway maintenance resulting from the diversion of branch line traffic can be quantified. These costs can then be viewed in the larger context of the general implications of branch line abandonment.

CHAPTER II

LITERATURE REVIEW

In dealing with branch line abandonment a society has two basic alternatives: first, provide a subsidy sufficient to provide an incentive to the railroad to maintain service, or second, incur the costs associated with abandonment. The burden on society, then, is to determine which alternative will maximize (minimize) net social benefits (costs) and then take the appropriate action.

Branch Line Subsidization

In discussing the first alternative, Wilson, Tyrchniewiez, and Mason (1981) have noted there are instances in which cooperative efforts between a railroad and community can maintain branch line service. They suggest that a possible solution in these instances would be to revise the current rate structure to include a specific rate, in addition to the through rate, for branch line service. Currently there are no differences between rates on branch line points of origin and mainline points of origin (Wilson et al., 1981). By instituting a surcharge for branch line service, shippers would face the opportunity cost of maintaining the line.

A surcharge for branch line service may present another problem, however, in that the price charged may be inefficient. This is because a large portion of the total cost of providing branch line service is independent of output (Wilson et al., 1981). The implication is that average costs are falling through the observed range of output, with marginal costs below average costs (Figure 3).

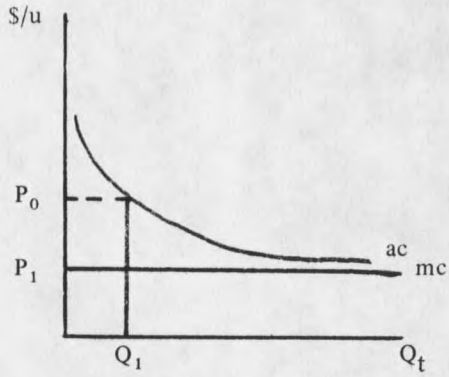

Figure 3. Cost curves for railroads.

Seneca endorses a similar cost structure when she states that the rail industry is exemplified by large, sunk physical investments in long term facilities. These investments are not transferable to other uses without large monetary losses. The result is that a long-term view of incremental costs is not appropriate; a large proportion of fixed costs remain fixed over any contemplated planning horizon. From this Seneca asserts that average costs are decreasing over the observed range of output, implying that marginal costs must lie below average costs.[1]

---

[1] Wilson, Tyrchiewiez, and Mason and Seneca assert that average and marginal costs are falling through the observed range of output. This may be a more restrictive conclusion than necessary, however, in that a high level of fixed costs only implies that average costs are falling, which in turn only implies that marginal costs must lie below average costs, and not that marginal costs must also be falling.

The functional form implied by Figure 3 is TC=F+VQ where TC is total costs, F is fixed costs, V is variable costs, and Q is output. This implies constant marginal costs (MC) equal to V:

$$MC = \frac{\partial TC}{\partial Q} = V$$

It further implies average costs (AC) which approach, but never reach, a minimum:

$$AC = \frac{TC}{Q} = \frac{F}{Q} + V$$

This functional form satisfies the argument that average costs are falling through the observed range of output, with marginal costs below average costs, but does not impose the restriction that marginal costs be declining.

The implication of such a cost structure is that the efficient price, i.e., price set equal to marginal cost (P_1 in Figure 3), will not recover total costs. The result of such a price structure could be a lack of incentive for railroads to provide branch line service over the long run. If, on the other hand, price is set at P_0, then any consumers willing to pay the marginal cost of service, but not average cost, would be eliminated from the market. This price would thus be inefficient because it deviates from the marginal cost of production (Wilson et al., 1981).

Baumol and Bradford (1970) (as well as Seneca) have asserted that in such a situation the traditional Pareto optimum price, where price is set equal to marginal cost, may not maximize social welfare. The contention is that in the case where pricing at marginal cost will not recover total costs, a second best, or Pareto quasi-optimal, pricing structure may be used to maximize social welfare (Baumol and Bradford, 1970). Baumol and Bradford have stated that the objective of such a pricing structure (subsidy) is one of the following:

1. the subsidy results in maximizing the sum of producers and consumers' surpluses.
2. the subsidy results in a price structure from which it is not possible to change with gainers compensating losers, or
3. the subsidy results in maximizing an individual's utility, given the utility level of every other individual.

All three of these alternatives basically maintain that a subsidy is warranted if it maximizes net social welfare.

The result of such a pricing technique is that a second best solution is achieved. While the price is not economically efficient (i.e., not set equal to marginal cost), market conditions may be such that this is the most efficient solution which can be achieved. Baumol and Bradford make this clear by referring to the problem as "maximization in the presence of an added constraint. Resource allocation is to be optimal under the constraint that

government revenues suffice to make up for the deficits . . . of individual firms that constitute the economy" (p. 265). This "second best" pricing technique is referred to as the Ramsey Pricing Principle, and is applicable when marginal cost pricing will not recover total costs (Baumol and Bradford, 1970).

In studying two rail lines in Canada, it was found that pricing at marginal cost would recapture 20-35 percent of the cost of providing rail service (Wilson et al., 1981). Wilson, Tyrchiewiez, and Mason concurred with Baumol and Bradford that subsidizing the resulting deficit, thus applying the Ramsey Pricing Principle, is justified if it can be shown that marginal benefits are equal to or greater than marginal costs.

Branch Line Abandonment

Probably the most comprehensive work computing the benefits and costs of branch line abandonment was by Baumel, Miller, and Drinka in 1976. They analyzed seventy-one branch lines in Iowa. The purpose was to determine the benefits and costs of rehabilitating each line and discuss the impacts of abandonment on communities and individual businesses (Baumel, Miller, and Drinka, 1976).

The 1976 study defined the benefits resulting from rehabilitation as:

> the total annual transportation and handling cost savings to grain shippers, fertilizer receivers, and shippers and receivers of other products if the line is upgraded rather than abandoned (p. 5).

The costs of upgrading were defined as:

> the total annualized cost of upgrading the line to 263,000-pound carrying capacity and to Federal Railroad Administration Class II Standards . . . plus the fixed cost of maintaining the line at that level of upgrading (p. 5).

The conclusion was that fifty-six percent of the seventy-one Iowa lines yielded a benefit-cost ratio of less than 0.25. Only eight of the lines produced a benefit-cost ratio greater than one (Baumel , Miller, and Drinka, 1977). This was attributed to the fact that there were so many lines in Iowa that the additional distance to another line was relatively

short, therefore the incremental costs of moving products to another line were small compared to the costs of line rehabilitation (Baumel et al., 1976). The Baumel et al. study did not fully account for highway impacts resulting from abandonment, however. The authors did recognize that such an impact exists (1976, p. 156), and even discussed a method to estimate such an impact (1976, p. 437), but did not apply the method to all seventy-one branch lines.[2]

The impact method was applied to three of the study lines, and the benefit-cost ratios of these lines were recomputed with the inclusion of the highway impact. The authors found that one line actually provided a net highway benefit from abandonment (or a cost to rehabilitation), but the other two lines did present a net highway cost from abandonment. On one of the two lines, the identified highway cost was $51,291 (Baumel et al., 1976). When the authors considered upgrading this line with new 115 pound rail, inclusion of highway impact changed the benefit-cost ratio from 0.08 to 0.13. When used 90 pound rail was used to upgrade the railroad, the benefit-cost ratio changed from 0.12 to 0.19 (Baumel et al., 1976). Similar changes were computed on the other line yielding a net highway impact; with new 115 pound rail the ratio changed from 0.17 to 0.22, and with used 90 pound rail the ratio changed from 0.29 to 0.34 (Baumel et al., 1976). From the analyses of these three lines, it was concluded that highway impact changed benefit-cost ratios only slightly, and therefore highway impact was not included in the analyses of the other sixty-eight lines (Baumel et al., 1976, p. 182).

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[2] The method used by Baumel, Miller and Drinka for computing highway impact basically consisted of collecting data on the estimated construction and maintenance costs resulting from one vehicle pass over one mile of road. This procedure assumed that optimal truck routings would take vehicles to a hard surface road as soon as possible. They then combined these routings and an estimate of the optimal number of pre- and post-abandonment trips with the estimated cost per vehicle pass. The difference between the pre- and post-abandonment costs became the incremental highway cost of branch line abandonment. This cost was then compared with the estimated increase in fuel and registration tax revenues caused by the increased truck traffic. The difference between highway costs and increased tax revenues was identified as net highway impact (Baumel et al., 1976).

The conclusion that highway impact is unimportant is questionable. Calculated benefit-cost ratios on five of the other sixty-eight lines were less than one, but would have exceeded one if the ratios were affected by the same magnitude from inclusion of highway impact as those on the two lines that were considered (Table 3). The implication that can be derived from these benefit-cost ratios is that highway impact, if explicitly considered in the calculation of benefits resulting from rehabilitation (or abandonment) may affect the suggested decision. There is no argument presented as to why highway impact was computed on lines with such low benefit-cost ratios initially, nor why one would not expect similar changes in benefit-cost ratios when considering highway impacts on lines with an initial ratio close to one.

Table 3. Benefit-Cost Ratios for Selected Branch Lines in Iowa.

	Benefit-Cost Ratios	
Line Name	Single-Car Rate	Multiple-Car Rate
Burt to Ledyard to Halfa		
New 115 pound rail	.59	.28
Used 90 pound rail	.94	.44
Estherville to Rake		
New 115 pound rail	.64	.77
Used 90 pound rail	.98	1.19
Mason City to Kesley		
New 115 pound rail	.64	.46
Used 90 pound rail	.81	.58
Moorland to Carroll		
New 115 pound rail	1.12	.71
Used 90 pound rail	1.41	.89
Carroll to Harlan		
New 115 pound rail	.99	.78
Used 90 pound rail	1.23	.97

Source: Baumel, Miller, and Drinka, 1976.

In 1982, the Montana Department of Commerce conducted a benefit-cost analysis on the rehabilitation of the Newlon Junction to Richey branch line (Montana Rail Plan, 1982). Benefits in this study were defined as "those economic impacts which could occur

after abandonment but which could be prevented by the continuation of rail service" (p. 4-8). Costs were defined as "the amount necessary to stabilize a line so that normal annual maintenance can then be made to keep the line at an appropriate standard . . . any economic disbenefits of [rehabilitation] were also counted as costs" (p. 4-8).

In discussing abandonment costs, the State of Montana study does recognize that an abandonment may adversely affect local roads. For the Newlon Junction to Richey line, however, highway costs were not considered in the benefit-cost calculations. The Department of Commerce estimated the increase in truck traffic to be about five vehicles per day. Based on this it was determined there would be no measurable incremental damage to highways from abandonment (Montana Rail Plan, 1982). The benefit-cost ratio calculated for the Newlon Junction to Richey line was 0.38. This was based on rehabilitation benefits of $3,416,100 and rehabilitation costs of $8,949,100 (Montana Rail Plan, 1982).

While consideration of highway impacts resulting from abandonment have been lacking in the economics literature, there has been some research by engineers. Purnell (pp. 23-24) suggests the following basic premise:

> any increase in the number or weight of motor carriers using a highway facility arising from rail service discontinuance will create a need for additional asphaltic concrete overlays on the highway forced to assumed additional truck passes.

Purnell goes on to suggest that any need for resurfacing affected highways to facilitate increased truck traffic is a cost which will have to be borne by state and/or local governments. Furthermore, if these costs are avoided initially by deferring the necessary maintenance and re-paving, the service life of the road will be reduced, resulting in a decline in pavement rideability and serviceability.

If the increase in truck traffic resulting from an abandonment can be estimated, it is possible to determine the level of highway impact which would be expected to result from the abandonment (Purnell, 1976). By identifying the expected level of highway impact,

one can estimate the economic impact on society, i.e., the increased costs of highway maintenance and/or use resulting from an abandonment.

In discussing highway maintenance expenditures as a function of vehicle traffic, the Organisation for Economic Cooperation and Development (OECD) makes a distinction between two types of maintenance; surface and structural. Surface maintenance, which refers to the restoration of road surface characteristics such as evenness, skid resistance, and impermeability, does not change as a function of heavy freight traffic or traffic increases (OECD, 1982). One would therefore not expect increases in surface maintenance costs from abandonment.

Structural maintenance refers to adapting a road so as to accommodate changes in traffic load, thus prolonging a road's useful life and compensating for accumulated fatique (OECD, 1982). Such maintenance usually encompasses pavement overlays. Structural maintenance is a function of both vehicle weight and traffic density; therefore a railroad abandonment may affect structural maintenance costs (OECD, 1982). In calculating the economic impact on highway structures resulting from branch line abandonment, therefore, it must be determined whether or not a sufficient amount of traffic is diverted to the highway to change the structural maintenance needs.

CHAPTER III

METHODOLOGY, BENEFIT-COST ANALYSIS, AND DATA REQUIREMENTS

Methodology

In analyzing objective one, estimation of highway impacts from abandonment, it is necessary to first specify a damage function. Such a function is a relationship between required pavement overlay and traffic density, measured in equivalent axle loads.

Purnell specified such a function (referred to as an impact graph) as:

$$f(\Delta t, \% \text{ EAL})$$

where Δt refers to required overlay thickness, and % EAL is the percentage increase in equivalent axle loads. Purnell's specification of this function is shown in Equation 1:

$$\Delta t = \frac{SN_A - SN_{NA}}{a_1} \tag{1}$$

where Δt is the required overlay thickness in inches, SN_A is the exact design structural number following increases in equivalent axle loads following abandonment, SN_{NA} is the design structural number with pre-abandonment traffic density, and a_1 is the surface layer coefficient related to the material being used for the surface layer of the pavement structure. A structural number (SN) is defined as:

> an index number derived from an analysis of traffic roadbed soil conditions, and regional factor thay may be converted to thicknesses of various flexible pavement layers through the use of suitable layer coefficients (a_1 in Equation 1) related to the type of material being used in each layer of the pavement structure (Van Til, 1972, p. 5).

Van Til defined the regional factor as "a numerical factor used to adjust the structural number of a flexible pavement structure for climatic and environmental conditions" (p. 5).

The American Association of State Highway Officials defined a layer coefficient (a_1 in Equation 1) as "[expressing] the empirical relationships between SN [structural number] and [pavement] thickness, and [measures] the relative ability of the material to function as a structural component of the pavement" (p. 53).

In order to solve Equation 1, the structural numbers corresponding to pre- and post-abandonment must be calculated. An equation for doing this has been identified by Van Til, and is reproduced as Equation 2:

$$SN = \frac{1.051\, W_{EAL}^{\,0.1068}\, R^{0.1068}}{10^{0.0397(S-3)}\; 10^{0.1068 G/\beta}} - 1 \qquad (2)$$

where W_{EAL} refers to equivalent axle loads, R is the regional factor, S is the soil support value (defined as "an index number that expresses the relative ability of a soil or aggregate mixture to support traffic loads through a flexible pavement structure" (Van Til, 1972, p. 5)), $G = \log 4.2 - P_t/4.2 - 1.5$ where P_t refers to the lowest road serviceability tolerated before resurfacing becomes necessary, and $\beta = .4 + 1096/SN+1$ (5.19). The structural number used in the calculation of β is an estimate of the resultant structural number. Purnell suggests a computer program which can be used to solve this equation for varying levels of post-abandonment equivalent axle loads (Appendix A). This program was utilized because of the complexity of Equation 2, and because the equation must be manipulated eleven separate times in deriving each damage curve presented in Chapter 4.

Before Equation 2 can be solved the pre- and post-abandonment equivalent axle loads must be computed. This involves three steps. The first step is to divide average daily traffic (ADT), such as those identified on the Montana Department of Highway's "Rural Traffic Flow May," by the total vehicles counted (TVC) over some time period. This yields an expansion factor (EP):

$$EP = \frac{ADT}{TVC}$$

The second step is to multiply the expansion factor by the number of commercial trucks (CT) in the total vehicle count. This calculates the average number of trucks per day (AT):

$$(AT) = (EP)(CT)$$

The third step is to multiply the average number of trucks per day by an equivalence factor (E). Van Til defined E to be "a numerical factor that expresses the relationship between a given axle load and an equivalent number of repetitions of an 18 thousand pound single-axle load" (p. 5). Equivalent axle loads (EAL) is then the product of the average number of trucks per day and the equivalence factor:

$$EAL = (E)(AT)$$

Solving Equations 1 and 2 for different levels of post-abandonment axle loads yields a series of points which map out an impact graph. For the Newlon Junction to Richey branch line a structural number for each ten percent (from 0 to 100 percent) increase in equivalent axle loads will be calculated with the resulting series of eleven points defining the impact curve. The graph will be defined by the required pavement overlay on the vertical axis and the percentage increase in equivalent axle loads on the horizontal axis, Figure 4.

Once an impact curve has been derived it can be used to derive an incremental cost curve. In general, an incremental cost curve shows the incremental cost (change in total cost) given a lump sum change in output. Thus:

$$IC = \frac{\Delta C}{\Delta Q}$$

where IC is incremental cost, ΔC is the change in total cost, and ΔQ is a change in output. This differs from a marginal cost curve because it deals with lumpy changes in output as opposed to infinitesimal changes in output. A marginal cost curve would measure the rate of change of total cost given an infinitesimal change in output (Hirshleifer, 1980). The importance of specifying an incremental cost curve is that it will show the estimated increase in highway damage associated with any given percentage increase in highway traffic.

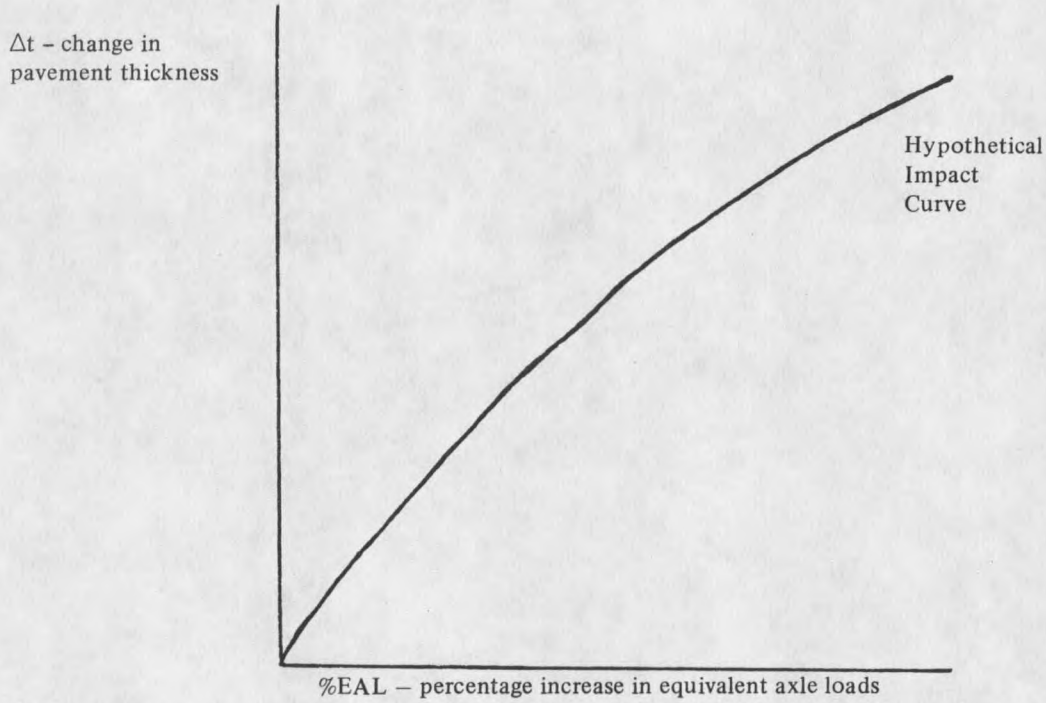

Figure 4. Hypothetical impact graph.

An incremental curve can be derived by multiplying the cost of a one inch pavement overlay by the pavement thicknesses corresponding to the vertical axis of the impact graph.[1] The cost curve, as shown in Figure 5, will show the highway damage costs (vertical axis) associated with any given percentage increase in equivalent axle loads (horizontal axis).

Once the impact graph and cost curve have been derived, the estimated increase in highway traffic caused by abandonment must be calculated. As discussed in Chapter 1, this will be done using the rail traffic movements on the Newlon Junction to Richey line between 1976 and 1982. Once this increased traffic volume has been estimated, the point

[1] In reality a three inch overlay, for example, does not cost three times as much as a one inch overlay. In most cases, however, the Montana Department of Highways applies a three inch overlay when resurfacing a road (Brunner, personal conversations). For this reason, Brunner suggested using one third the cost of a three inch overlay in estimating the cost of a one inch overlay. Using this method, highway impact costs will be estimated relative to the cost of a three inch overlay.

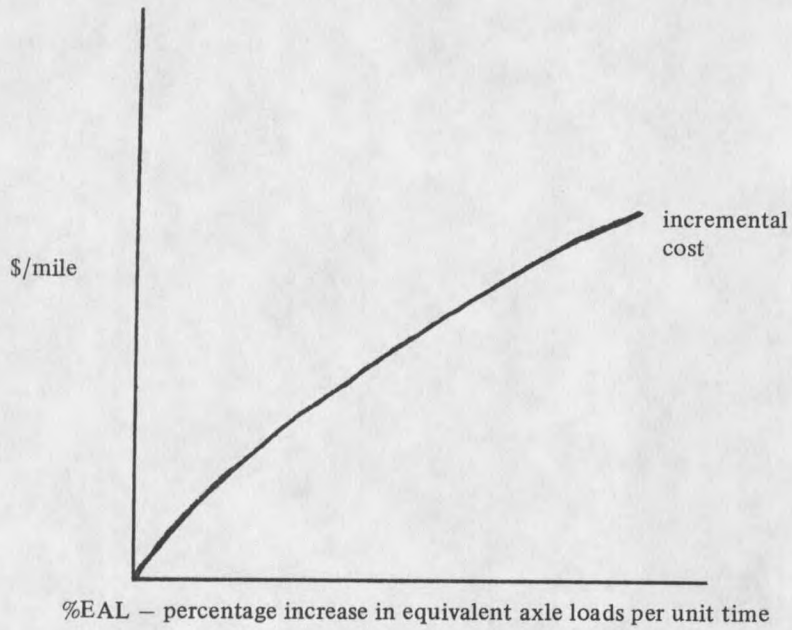

Figure 5. Incremental cost curve for highway impact.

corresponding to the traffic volume on the cost curve can be found and the associated cost read off the vertical axis.

Economics of Benefit-Cost Analysis

The second study objective, discussing why calculating highway impact is important, is dealt with in the context of benefit-cost analysis. Sassone and Schaffer have defined benefit-cost analysis as "an estimation and evaluation of net benefits associated with alternatives for achieving defined public goals" (1978, p. 3). They further state that benefit-cost analysis is a generic term which incorporates several different procedures which estimate the benefits and costs of alternative decisions.

Benefit-cost analysis is generally seen as an applied area of welfare economics (Eckstein, 1958). Its purpose is to identify the relative desirability of different economic conditions (Sassone and Schaffer, 1978). This involves two steps. First, one or several criteria

are established by which to judge alternate states, and second, the states are evaluated according to the specific criteria. Sassone and Schaffer identify four criteria that are generally used. These are: (1) unanimity, (2) Pareto superiority, (3) majority rule, and (4) potential Pareto superiority.

The unanimity criterion states that one economic state is socially superior to another if each member of society (or firm or community) prefers the first state to the second (Sassone and Schaffer, 1978). This criterion presents a problem, however, in that unanimous agreement must be reached. In a situation where there is not unanimous agreement, the criterion cannot suggest a socially optimal state. Thus, it may be of limited usefulness in a decision making process.

The second criterion, Pareto superiority, means that one state is socially superior to a second state if at least one person prefers the first to the second, and no one prefers the second to the first (Sassone and Schaffer, 1978). While this criterion is less restrictive than unanimity, it still allows for no dissension as to the preferred state. All who do not prefer the first state must at least be indifferent between the first and the second. Thus, it too has its limitations in practical application.

The majority rule criterion infers that one state is socially superior to a second if a majority of society prefers that state (Sassone and Schaffer, 1978). A problem with this criterion is that the decision process is usually one step removed from the individual. Individuals vote for elected officials, and the preferences of those elected are usually counted. This implies two assumptions regarding individual utility functions. It first assumes that elected officials possess information on each individual's utility function, and second, that they are capable of conducting interpersonal utility comparisons and thereby determine a state which would be socially preferred. These assumptions imply that the decision maker has some knowledge of a social welfare function, and as such can make tradeoffs on

behalf of society which provide a net benefit to society; i.e., increase societies' aggregate utility. Since social welfare is a concept which cannot be accurately quantified (i.e., interpersonal utility comparisons cannot be objectively conducted), such a criterion is impotent in economic analysis (Beattie et al., 1971).

The potential Pareto superiority criterion suggests one state is socially superior to a second state if the gainers from the first over the second state could compensate the losers, and if that compensation made no one worse off than they would have been in the second state (Sassone and Schaffer, 1978). While this criterion is more complicated than the previous ones, it has the most common application. By totaling the benefits and costs from moving from one state to another, and then comparing the benefits with the costs, it is possible to estimate if gainers could compensate losers (i.e., if benefits exceed costs). If this is possible, then the new state is defined as superior to the old. If compensation is not possible, the old state is superior.

It should be noted that the potential Pareto superiority criterion defines a superior state based on economic efficiency, i.e., benefits must be equal to or greater than costs. The objective of most public programs, however, is not simply economic efficiency (Maass, 1966). The result is that such a narrowly defined criterion, while satisfying an economist's needs in terms of workability, may not be comprehensive enough to provide the sole basis upon which to determine the outcome of public decisions. Such decisions are made in the political arena, and usually involve a tradeoff between competing criteria. For example, society may be more concerned with redistributing income than maximizing economic efficiency in some instances (Maass, 1966).

In order to accurately project whether or not some new state is superior to the existing state based on the potential Pareto superiority criterion, all benefits and costs associated with the new state must be calculated. If the calculation of benefits and costs is not comprehensive (i.e., all possible benefits and costs are not considered) then the results of the

analysis should not be interrupted as indicating one state is superior to another. This lack of comprehensive analysis is prevalent in consideration of branch line abandonments, however, in that highway impacts have not been explicitly considered.

By successfully satisfying the first objective of this study a method to calculate the highway impacts of abandonment will be identified. The result will be that more comprehensive calculations of the total benefits and costs of abandonment can be obtained. From this socially superior levels of rail activity can be determined based on the potential Pareto superiority criterion.

Data

In order to estimate the highway damage caused by a branch line abandonment, data must be collected on the pre-abandonment condition of the road, historic traffic density of the rail line, expected changes in commodity movements resulting from abandonment, and values for the area's regional factor, soil support value, and structural design number used in Equations 1 and 2.

These data for the Newlon Junction to Richey line were collected through surveys, by the author, of the affected highway; interviews with affected rail shippers; interviews with personnel of the Montana Department of Highways; and from the 1982 Annual Update of the Montana Rail Plan.

In general, Montana Highway 200 appeared to be in poor condition. This determination was made by Dr. Paul Jennings based on the author's survey of the road site.[2] The survey was based on an assessment made of the road at every second mile marker. The assessment included measuring the length and width of cracks in the road surface, and noting whether they ran parallel or perpendicular to traffic movement. In addition, the

[2] Dr. Jennings is a Professor of Chemistry at Montana State University. In addition, he is recognized as a pavement expert. His assessment was that the highway was in poor condition indicating it would need to be totally reconstructed in the next five to ten years.

depth, width, and length of all ruts and potholes visible at each survey site were measured. Their position in the road surface was also noted (i.e., whether they were in the east or west bound lane, the driver's or passenger's side of the lane, or found in the shoulder). Based on this survey, Jennings estimated the serviceable life left in the road. His opinion was that, even in the absence of abandonment, Montana Highway 200 will need total reconstruction in the next five to ten years.

In order to determine the movement of grain after an abandonment, interviews were conducted with individual shippers along the line (Appendix B). The interviews revealed that, in the event of branch line abandonment, freight currently moved by the railroad would move by truck across Highway 200 to either Circle or Sidney. The elevator operators felt unanimously that they could receive grain locally and truck in bulk to fifty-two car facilities in Sidney or Circle at a lower cost than individual farmers could truck to elevators in Sidney or Circle. Two of the five elevators on the line merged with elevators on other lines (one with an elevator in Sidney and one with an elevator in Circle) with fifty-two car capacities. Both anticipate buying grain at the local elevator at post-abandonment rates competitive with current prices. The interviews coupled with the observation that Highway 200 is the only primary road serving the area led to the assumption that all rail traffic would be diverted to Highway 200 in the instance of abandonment.

To estimate the volume of traffic diverted to Highway 200 from an abandonment, the arithmetic mean plus and minus one standard deviation for the years 1976 through 1982 was computed. Table 4 provides an overview of traffic density for these years. The mean traffic level was 479.7 cars per year, with a standard deviation of 286.56. From the interviews with shippers it was determined that these were predominantly 100 ton hopper cars. This implies that, under an abandonment scenario, one would expect an increase in truck freight moving over Highway 200 of 47,970 tons (± 28,656 tons) per year. This estimate will be used to estimate the expected yearly increase in truck traffic on Highway 200.

Table 4. Traffic Volume for the Newlon Junction to Richey Branch Line, 1976-1982.

Year	Traffic Volume # of Cars
1976	801
1977	450
1978	649
1979	865
1980	389
1981	107
1982	97

Arithmetic Mean for Traffic (μ) = 479.7 cars
Variance (S^2) = 82,117,92 cars
Standard Deviation (S) = 286.56 cars

Sources: Montana Rail Plan, 1982; interviews with shippers.

CHAPTER IV

RESULTS

The first step in estimating the potential highway impact which would result from an abandonment of the Newlon Junction to Richey branch line was to specify a highway damage function for the area. To do this the pre-abandonment equivalent axle loads for Highway 200 were calculated.

The "Rural Traffic Flow Map" identified the average daily traffic count for Highway 200 to be 250 vehicles per day. On February 24, May 11, and July 22 of 1982 the Montana Department of Highways counted a total of 703 vehicles on the highway. These figures were used to compute an expansion factor of 0.3556 (as discussed in Chapter 3):

$$\frac{250}{703} = 0.3556$$

The total number of trucks counted for the same period (February 24, May 11, and July 22) of 1982 was 91. This was combined with the expansion factor to derive the average number of trucks per day for Highway 200:

$$(0.3556)\,(91) = 32.3596 \text{ trucks per day}$$

This number was multiplied by an equivalence factor of 1.955 (as identified by Bob Lambert of the Montana Department of Highways). The result was pre-abandonment axle loads per day (EAL)[1] :

[1] Under conditions of heavy vehicle traffic, trucks must be broken into several categories (say 2000 pound increments) and a separate traffic equivalence factor must be used for each category in order to determine individual equivalent axle loads. These are then used to compute a mixed traffic equivalent axle load. Most areas of Montana, however, experience such light volumes of traffic that an average traffic factor for all traffic (such as 1.955 for the Richey area) provides accurate results (Lambert, personal conversations).

$$(32.3596)\,(1.955) = 63.263 \text{ daily EAL's}$$

Thus Montana Highway 200 was estimated to have a pre-abandonment equivalent axle load level of 63.263.

Next, the structural number associated with this level of equivalent axle loads was derived by Equation 2, reproduced here as follows:

$$SN = \frac{1.051\, W_{EAL}^{\,0.1068}\, R^{0.1068}}{10^{0.0397(S-3)}\; 10^{0.1068 G/\beta}} - 1 \qquad (2)$$

Gene Peterson of the Maintenance Division, Montana Department of Highways supplied values for the regional factor (R), the soil support value (S), the terminal serviceability index (P_t used in the calculation of G), and the initial estimate of the structural number (SN used in the calculation of β). The values used were 2.5, 2, 2.5, and 3.5 respectively (Table 5). The pre-abandonment equivalent axle load calculation was combined with these numbers in Equation 2 to derive the pre-abandonment structural number:

$$SN = \frac{(1.051)\,(63.263^{0.1068})\,(2.5^{0.1068})}{10^{0.0397(2-3)}\; 10^{(0.1068)\log \frac{4.2-2.5}{4.2-1.5}\,/.4 + \frac{1096}{(3.5+1)^{(5.19)}}}} - 1$$

The resulting pre-abandonment structural number was 0.9818.

Next the structural numbers corresponding to ten percent increases in equivalent axle loads (up to 100 percent) were calculated (Table 6). Equation 1 was then used to calculate the change in pavement thickness required to accommodate the increase in equivalent axle loads at existing road serviceability levels:

$$\Delta t = \frac{SN_A - SN_{NA}}{a_1} \qquad (1)$$

In Chapter 3 Δt was defined as the required pavement overlay in inches, SN_A and SN_{NA} were the structural numbers associated with abandonment (increased equivalent axle loads) and no abandonment (initial equivalent axle loads) respectively, and a_1 was the surface

Table 5. Values for Regional Factor, Soil Support Value, Terminal Serviceability Index, and Structural Number.

Variable	Value
Regional Factor (R) – A numerical index used to adjust the structural number of flexible pavements for climate and environment.	2.5
Soil Support Value (S) – An index which describes the ability of a soil to support traffic loads on a flexible pavement.	2
Terminal Serviceability Index – A number which describes the condition of the road from 5 (excellent) to 0 (poor).	2.5
Structural Number (SN) – A number derived from existing soil conditions and regional factor that may be converted to thicknesses of flexible pavement layers.	3.5
Layer Coefficient (a_1) – A number which measures the ability of construction material to function as a structural component of the pavement.	0.33

Source: Peterson, Montana Department of Highways.

Table 6. Calculated Effects of a Branch Line Abandonment on Montana Highway 200.

EAL (10% increases)	SN	Δt-Overlay Thickness in Inches	Incremental Cost of Overlay/Mile
63.263	.9818	0	0
69.589	1.0023	.0621	1,741.84
75.915	1.0212	.1194	3,349.04
82.241	1.0388	.1727	3,441.60
88.567	1.0552	.2224	6,238.07
94.893	1.0706	.2691	7,547.95
101.219	1.0851	.3130	8,779.30
107.545	1.0988	.3545	9,943.33
113.871	1.1119	.3942	11,056.87
120.197	1.1243	.4318	12,111.51
126.523	1.1361	.4676	13,114.98
For a 14 percent EAL increase:			
73.5254	1.0143	.0985	2,762.39

layer coefficient. Peterson identified the surface layer coefficient for the Richey area as 0.33.

With a ten percent increase in equivalent axle loads on Highway 200 (from 63.263 to 69.589), the structural number for the highway (using Equation 2) changes from 0.9818 to 1.0023. Substituting the structural numbers from the initial and 10 percent increase in equivalent axle loads into Equation 1 yields a required pavement overlay of 0.0618 inches to maintain initial road serviceability levels:

$$\Delta t = \frac{1.0023 - 0.9818}{0.33}$$

$$= 0.0618$$

This same calculation was made for equivalent axle load increases from 0 to 100 percent (at ten percent intervals) and the resulting points (associated with required thicknesses of pavement overlays) were plotted. The impact graph in Figure 6 was mapped through these points. The graph shows the required overlay thickness needed to maintain initial road serviceability levels for a given percentage increase in equivalent axle loads.

After the impact graph is derived, it can be used to specify an incremental cost curve. This curve depicts the incremental costs associated with a given percentage increase in equivalent axle loads. This relationship is developed by multiplying the overlay thicknesses identified on the vertical axis of the impact graph by the cost of applying a one inch pavement overlay. Brunner identified this cost as being $28,048.88 per mile. The vertical axis of the incremental cost curve, then, refers to the added highway impact in dollars per mile, and the horizontal axis refers to the percentage increase in equivalent axle loads. The incremental cost curve derived for the Newlon Junction to Richey branch line is shown in Figure 7.

In order to estimate the actual highway cost from an abandonment of the Newlon Junction to Richey branch line, estimates of the percentage increase in equivalent axle

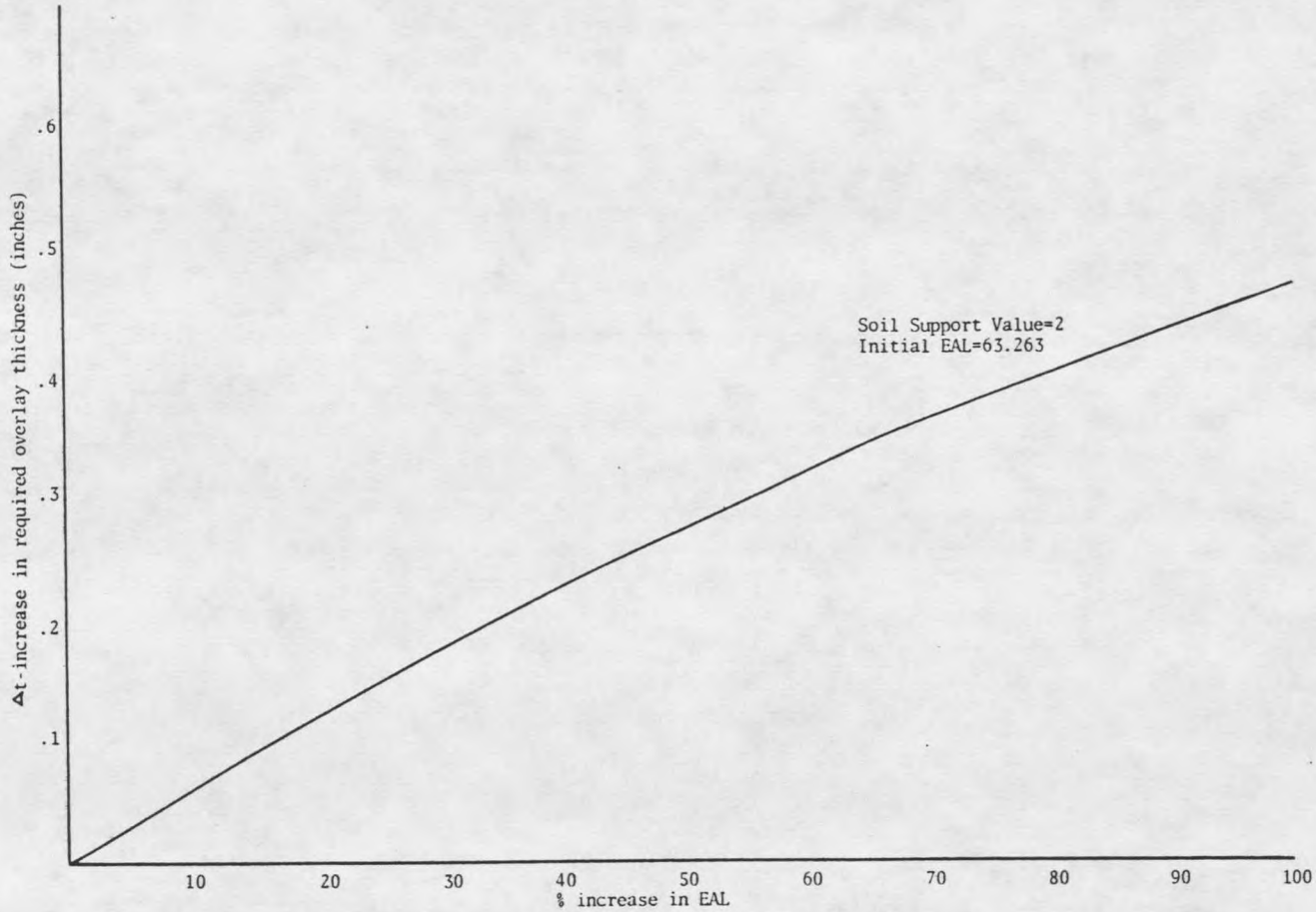

Figure 6. Highway damage curve for the Newlon Junction to Richey line.

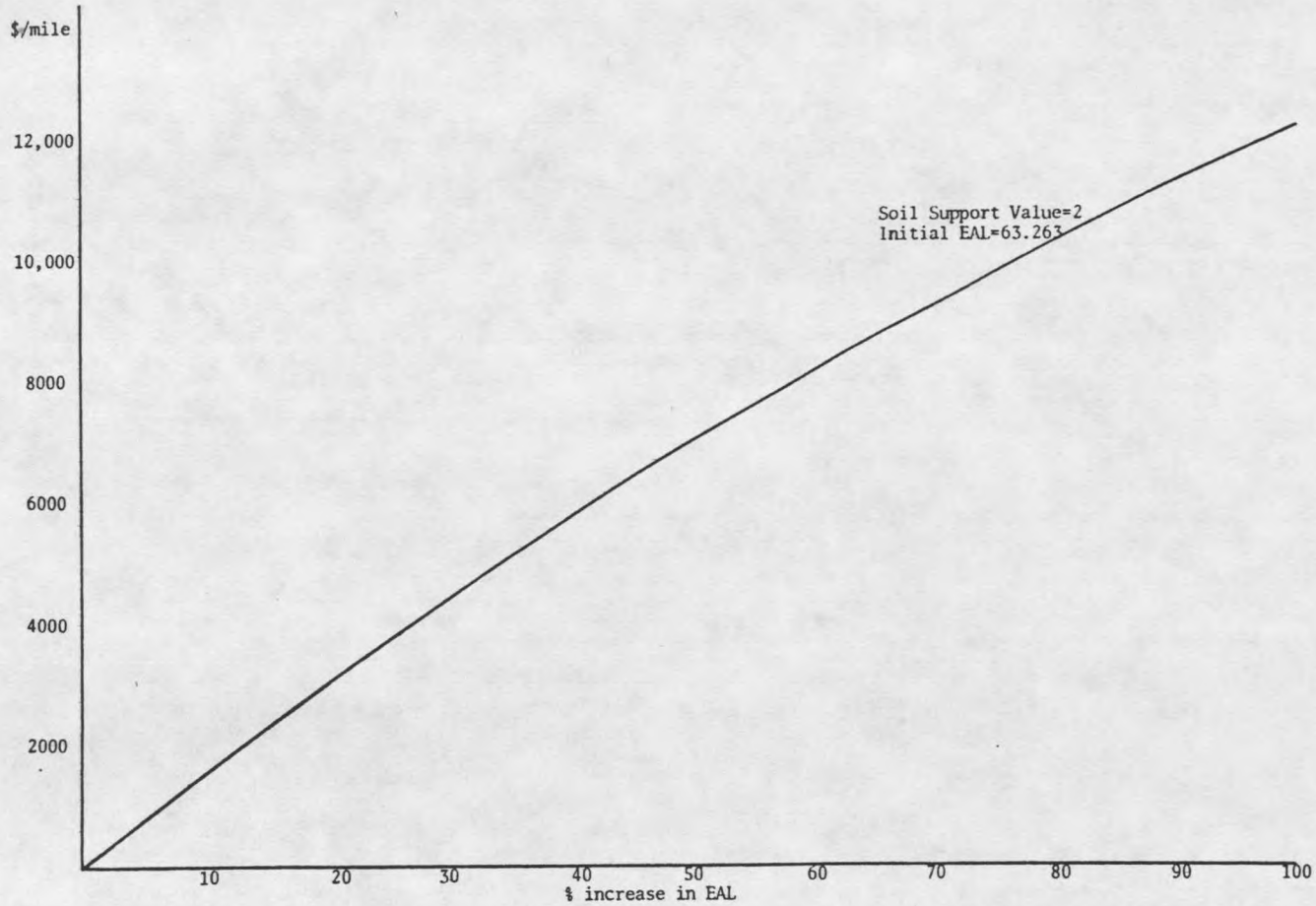

Figure 7. Incremental highway costs for the Newlon Junction to Richey line.

loads were estimated. This was done by first calculating the number of 80,000 pound semi-trucks needed to carry the freight moved over the rail line in one year.

The average annual rail traffic for the Newlon Junction to Richey line between 1976 and 1982 was 479 one-hundred ton hopper cars. This implies that 47,900 tons of freight have moved over the line annually. Multiplying this number by 2000 (to convert tons to pounds) yields 95,800,000 pounds of rail freight annually. The average pay-load of an 80,000 pound semi is 50,000 pounds (Frickle, personal conversations). Therefore, 1916 trucks (95,800,000 ÷ 50,000) would be required to move the freight moved by the railroad in a year. This represents an estimate of the increase in annual truck traffic that would result from an abandonment of the Newlon Junction to Richey rail line. Dividing 1916 trucks per year by 365 days gives an estimate of the increase in trucks per day after abandonment:

$$\frac{1916}{365} = 5.2493 \text{ increase in trucks per day}$$

It is interesting to note that this is the same increase estimated in the 1982 Montana Rail Plan. Adding this to the pre-abandonment calculation of trucks per day yielded total trucks per day after abandonment:

$$(32.3596) + (5.2493) = 37.6089 \text{ trucks per day after abandonment}$$

This was then combined with the traffic equivalence factor to derive an estimate of the equivalent axle loads after abandonment:

$$(37.6098)(1.955) = 73.5254 \text{ EAL's after abandonment}$$

Dividing this into the pre-abandonment equivalent axle loads and subtracting from one (1) to derive the percentage increase in equivalent axle loads resulting from abandonment yields:

$$1 - \frac{63.2630}{73.5254} = 13.96 \text{ \%EAL increase}$$

Thus, the percentage increase in equivalent axle loads on Highway 200 resulting from an abandonment of the Newlon Junction to Richey branch line (based on the mean rail traffic from 1976-1982) was estimated at about fourteen percent. From Table 6 and Figure 7 it is apparent that a fourteen percent increase in equivalent axle loads causes an estimated incremental highway damage cost amounting to $2762 per mile.

The standard deviation associated with the computation of average rail traffic per year for the Newlon Junction to Richey line was 287 cars per year (see Table 4). The estimated range of increased truck traffic based on the mean plus and minus one standard deviation was between 1.32 and 8.39 trucks per day. Adding these numbers to the pre-abandonment level of trucks per day yields a range of post-abandonment trucks per day of between 33.6796 and 40.75. Multiplying each of these by the traffic equivalence factor yields an expected range of post-abandonment equivalent axle loads between 65.8436 and 79.6663. These figures correspond to a percentage increase in equivalent axle loads of between four and twenty-one percent.

Based on the above calculations the expected incremental cost of highway damage caused by an abandonment is between $704 and $4148 per mile. Given that the affected section of Montana Highway 200 stretches a total of 71 miles, the incremental cost of highway damage for the entire section of road is estimated to be between $49,982 and $294,496.

If this range of costs is viewed as a benefit of branch line rehabilitation, the benefit-cost ratio computed by the Montana Department of Commerce for the line can be recomputed accounting for the estimated highway impact. As noted in Chapter 2, the estimated benefits of rehabilitation were $3,416,100, costs were $8,949,100, and the benefit-cost ratio was 0.38. By adding the highway cost at the lower end of the range to the benefits of rehabilitation, total benefits become $3,446,082. The benefit-cost ratio thus changes from 0.38 to 0.39. When the maximum cost is considered, total rehabilitation benefits

become $3,710,596. This increases the benefit-cost ratio from 0.38 to 0.42. While this ratio is still not close to one, it is a measurable change.

It is important to note, however, that this benefit-cost ratio may still underestimate total benefits to the community resulting from branch line rehabilitation. This is because the benefit-cost calculations were computed from the standpoint of benefits and costs to the railroad (Craig, personal conversations), and as such may have excluded community benefits other than highway damage caused by abandonment. For example, if rehabilitating a line would prevent a firm from going out of business, this should be counted as a benefit of rehabilitation. While the Rail Plan discusses such potential benefits in its general discussion of benefit-cost analysis, it does not explicitly state if or how these were accounted for in any of the individual analyses. The costs and benefits which are explicitly defined accrue directly to the railroad.

The total rehabilitation costs of the branch line have been estimated at $5.1 million (Montana Rail Plan, 1982). Net profit on the line in 1980 was $172,000 (Montana Rail Plan, 1982). Furthermore, the line experienced a much higher volume of freight traffic in 1980 than 1981 or 1982 (see Table 4). Therefore, profits are assumed to have declined since 1980. The implication, then, is that if the community (or State) wishes to maintain service by subsidizing the line, it may involve subsidizing the costs of rehabilitation. Even if the benefits in the benefit-cost calculations in the Rail Plan were doubled to compensate for excluded community benefits, subsidizing the line would not be cost effective given the high cost of rehabilitation. It seems improbable that excluded benefits would raise the benefit-cost ratio to or near one given the low ratio initially.

Figure 8 depicts two impact graphs representing the expected upper and lower bounds for incremental impacts on all Montana highways resulting from increases in freight traffic. The points plotted in deriving these curves are presented in Table 7. The lower curve assumes a soil support value of 6 and an initial equivalent axle load level of 50. This shows

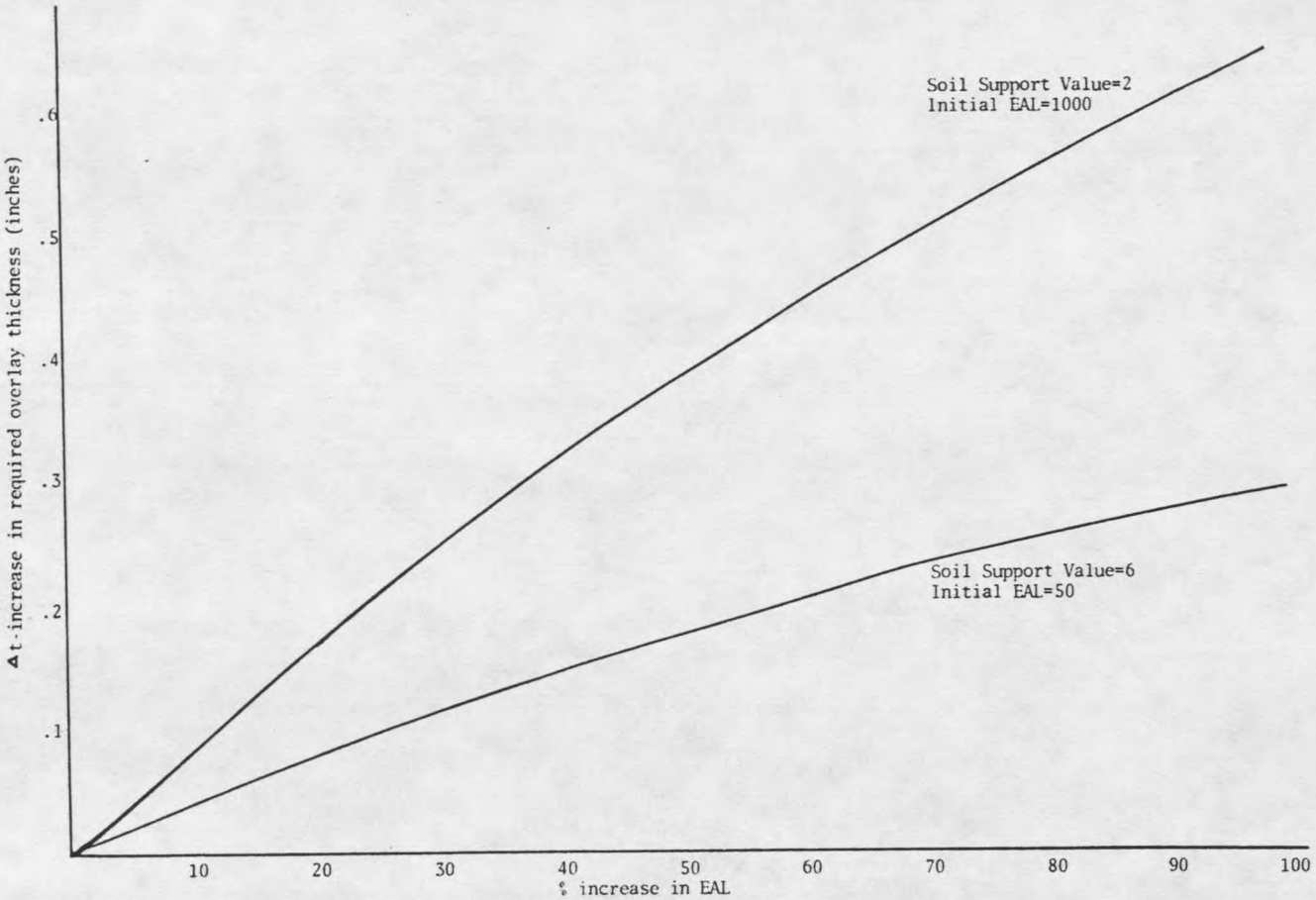

Figure 8. Expected range of highway impact in Montana.

the incremental damage resulting from traffic increases on a road with a stable base (as reflected in the high soil support value) and a low initial traffic level. The upper curve assumes a soil support value of 2 (relatively unstable) and an initial equivalent axle load of 1000. This curve shows the incremental damage associated with traffic increases on a road with a relatively unstable base and a high initial traffic volume.

Table 7. Calculated Points Associated With the Limits of Expected Highway Damage from Branch Line Abandonment in Montana.

EAL (10% increases)	SN	Δt-Overlay Thickness in Inches	Incremental Costs of Overlay/Mile
	Upper Boundary – Soil Support = 2, Initial EAL = 1000		
1000	1.6799	0	0
1100	1.7086	.0870	2,440.25
1200	1.7350	.1670	4,684.16
1300	1.7596	.2415	6,773.81
1400	1.7827	.3115	8,739.23
1500	1.8043	.3770	10,574.43
1600	1.8248	.4391	12,316.26
1700	1.8441	.4976	13,957.12
1800	1.8625	.5533	15,519.45
1900	1.8800	.6064	17,008.84
2000	1.8968	.6573	18,436.53
	Lower Boundary – Soil Support = 6, Initial EAL = 50		
50	.3384	0	0
55	.3521	.0415	1,164.03
60	.3647	.0797	2,235.50
65	.3765	.1155	3,239.65
70	.3874	.1485	4,165.26
75	.3977	.1797	5,040.38
80	.4074	.2091	5,865.02
85	.4165	.2367	6,639.17
90	.4252	.2630	7,376.86
95	.4330	.2882	8,083.69
100	.4414	.3121	8,754.06

Brunner has indicated that soil support values in Montana can be expected to fall between two and six. In light of this, the area between the two curves in Figure 8 defines a range in which the expected incremental damage from traffic increases on any Montana highway would be expected to fall.

Figure 9 shows two incremental cost curves which were derived from the impact graphs in Figure 8. The area between these curves represents the range in which the incremental cost (per mile) associated with a traffic increase on any Montana highway would be expected to fall.

It should be noted that there is little difference between the upper and lower bounds of the cost curves when small increases in traffic are considered, but the range of costs increases as larger percentage increases in traffic are considered. With a ten percent increase in equivalent axle loads, for example, the required pavement overlay would range between 0.04 inches for a road with a high soil support value and a low initial traffic level and 0.08 inches for a road with a low soil support value and high initial traffic volume. The corresponding range of highway damage costs would be between $1000 and $2000 per mile. If a ten percent traffic increase is assumed for the Newlon Junction to Richey branch line, and the benefit-cost ratio for the line is recommended using the upper and lower bounds of the cost range from Figure 9, the benefit-cost ratio for branch line rehabilitation changes from 0.38 (the initial benefit-cost ratio computed in the 1982 Rail Plan) to 0.39 if the highway has a high soil support value and a low traffic volume, and 0.40 if the highway has a low soil support value and a high traffic volume. If a higher percentage increase in traffic is assumed (for example, seventy percent), then the difference in the benefit-cost ratios using the upper and lower bounds from Figure 9 becomes much greater. For a seventy percent traffic increase, the required pavement overlay would range between 0.23 inches for a high soil support value and a low traffic volume, and 0.5 for a low soil support value and a high traffic volume. The corresponding highway damage cost would be between $6500 and $14,000 per mile. Using these cost figures to calculate the benefit-cost ratio for the Newlon Junction to Richey branch line would change the ratio from 0.38 to 0.43 for a road with a high soil support value and low traffic volume, and 0.49 for a road with a low

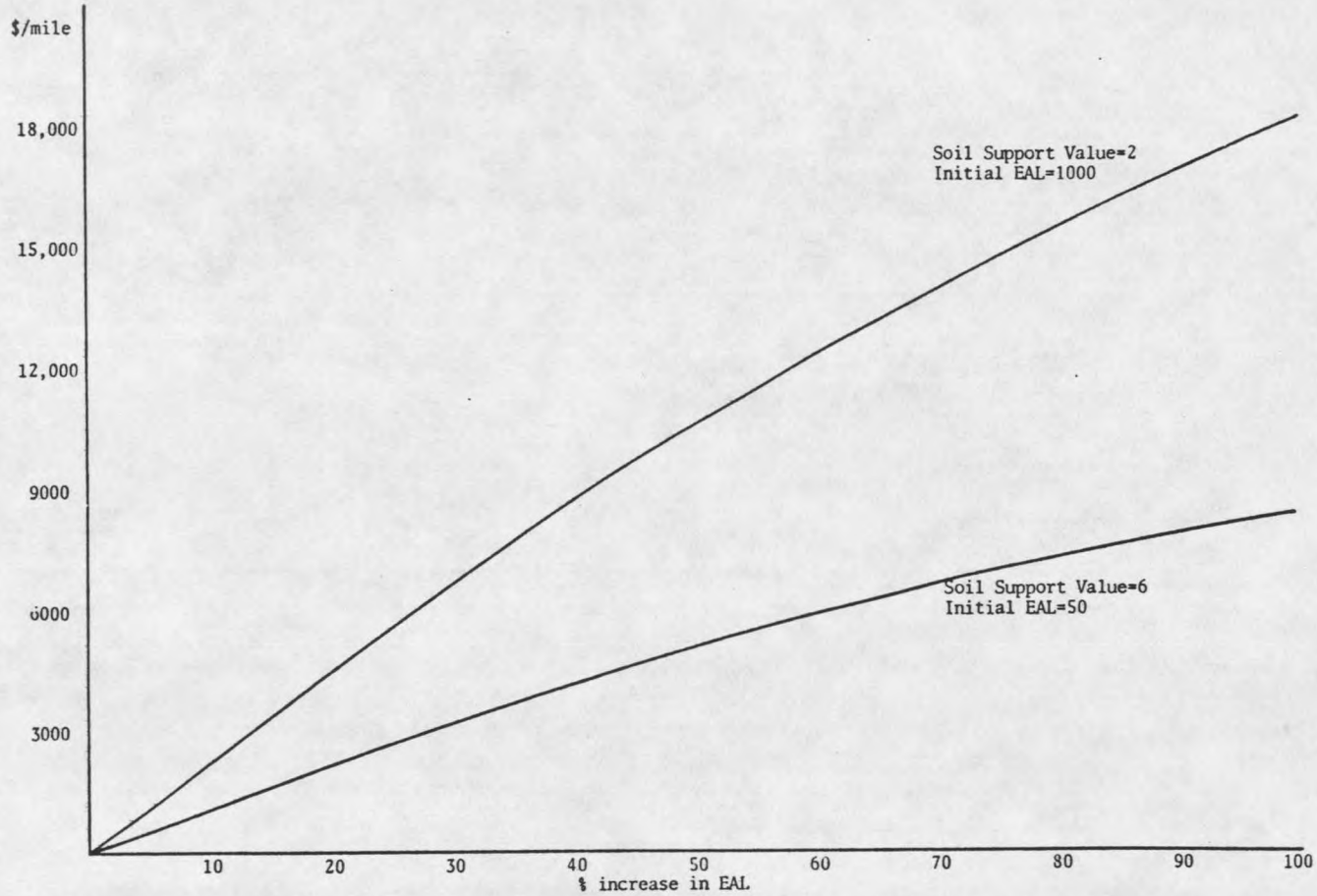

Figure 9. Expected range of incremental highway costs in Montana.

soil support value and a high traffic volume. The implication is that estimates of soil support value and initial equivalent axle loads are not as critical in estimating the highway impact cost associated with small percentage increases in traffic, but become more critical the larger the percentage increase in traffic.

CHAPTER V

SUMMARY, IMPLICATIONS, AND CONCLUSIONS

Summary

The objectives of this study were to first present a method to estimate highway impacts of rail line abandonment and apply it to a specific study site, and second, discuss why this cost is important in considering the overall cost of abandonment on a given community.

From a discussion of the relevant literature it was shown that highway impact has usually been omitted from benefit-cost calculations of branch line abandonment (or rehabilitation). It was also shown that some analyses which excluded highway impact produced benefit-cost ratios very close to one, and had highway impact been considered the outcome of the analyses may have been affected.

By computing the highway impact resulting from an abandonment of the Newlon Junction to Richey branch line it was shown that even small increases in truck traffic resulting from abandonment can affect a highway's serviceability level. It was further shown that this resultant damage can be quantified in monetary terms. By re-computing the benefit-cost ratio associated with rehabilitating the Newlon Junction to Richey branch line with estimated highway impact included, evidence was presented which showed that incorporation of these costs has relatively small effects on benefit-cost ratios of branch line abandonment; the benefit-cost ratio for the Newlon Junction to Richey changed from 0.38 to between 0.39 and 0.42 when highway costs resulting from branch line abandonment were accounted for. The implication is that previous analyses on branch line abandonment

have typically underestimated abandonment costs. The resulting benefit-cost ratios, therefore, may not have accurately projected the socially superior state of rail line activity as defined by the potential Pareto superiority criterion.

The procedure used to estimate highway damage for the Newlon Junction to Richey branch line was also used to identify a range of highway impacts and costs which could be expected to accrue given an abandonment of any branch line in Montana. The upper limit of the range assumed a soil support value of 2 (relatively unstable) and an initial equivalent axle load of 1000. The lower limit assumed a soil support value of 6 and an initial equivalent axle load of 50. The conclusion drawn from the expected range of impact is that estimation of soil support values and initial equivalent axle loads is not as critical in estimating highway impacts when small percentage increases in traffic are considered, but become increasingly important the greater the percentage increase in traffic volume. Similarly, highway impact resulting from small percentage increases in traffic may affect the outcome of a benefit-cost ratio concerning abandonment only slightly, while the damage resulting from larger percentage increases in traffic will affect a benefit-cost ratio by a greater magnitude.

Implications

While it is clear that excluding highway damage from the benefit-cost calculation on the Newlon Junction to Richey branch line underestimated the total costs to the community of an abandonment, it is equally clear that including highway damage will not raise the benefit-cost ratio close to one. The implication is that it would not be cost effective for the community (or State) to avoid abandonment costs by subsidizing the branch line. The benefit-cost ratio computed with highway impact included still suggests that the costs of rehabilitating the line and maintaining service would outweigh the benefits in excess of

two to one (a benefit-cost ratio of 0.5 would suggest costs exactly twice benefits; the highest computed benefit-cost ratio calculated for the study line was 0.42).

Important to note, however, is that the costs of rehabilitating the line would probably be, at least partially, a burden passed on to the entire state (Montana Rail Plan, 1982). Tangible benefits, on the other hand, would tend to accrue to the local community. The result is that there may be strong support in the community for branch line rehabilitation. If the costs of branch line rehabilitation were levied on the state tax base in general, then the benefits to the community from rehabilitation may exceed local costs by a wide margin. In such a situation, one might expect community support for rehabilitation in order to avoid the localized costs associated with abandonment.

Conclusions

To the extent that a benefit-cost analysis is conducted to assess all benefits and costs associated with a given state, there seems to be no theoretical or empirical basis for excluding highway impact in analyses of the benefits and costs of branch line abandonment. This study has identified a method to calculate highway impacts resulting from increased truck traffic. It is hoped that it provides an acceptable argument for explicit consideration of these costs in further studies, and as such an incentive to consider a more comprehensive perspective when considering the effects of branch line abandonment on a community. Even though the impacts of rail line abandonment on highways is relatively small compared to other abandonment costs, it is obvious that consideration of highway impact can affect a benefit-cost ratio in the margin, and thus affect the suggested decision of a benefit-cost ratio which is close to one.

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APPENDICES

APPENDIX A

FORTRAN Program for Computing Structural Numbers

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FORTRAN Program for Computing Structural Numbers

```
      REAL K
      REAL J
5     OUTPUT "ENTER C,W,SN,S"
      INPUT C,W,SN,S
      IF (G.EQ.99) GO TO 90
      OUTPUT G,W,SN,S
      N=0
10    N=N+1
      K=G / (.4+1094./(SN+1) **5.19)
      J=1 / (10.**(.0397*(S-3)))
      SC=1.051*(W**.1068)*(2.5**.1068)*J / (10.**(.1068*K))-1
      IF((ABS(SC-SN)-.01).LE.0.0) GO TO 30
      OUTPUT "NOT YET",N,C,W,S,SN,SC
      IF (N.EQ.25) GO TO 5
      SN=SC
      GO TO 10
30    OUTPUT "GOT IT",N,G,W,S,SN,SC
      GO TO 5
90    STOP
      END
```

APPENDIX B

Interview Questions

APPENDIX B

Interview Questions

The following are a series of questions around which verbal interviews were conducted with each of the shippers on the Newlon Junction to Richey branch line. The interviews were conducted in late September, 1983.

1) Do you expect that the Newlon Junction to Richey branch line is likely to be abandoned?
2) If the line is abandoned, do you expect to cease operating from your present location?
3) What would be your anticipated destination, route, and mode of product delivery in the instance of an abandonment?
4) Would you expect to serve the same clientele after an abandonment as you now serve?
5) How many loaded rail cars have you shipped annually for the years 1976 through 1982?
6) Were these predominantly 100 ton hopper cars or box cars?

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