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RAILROAD ELECTRIFICATION IN AMERICA'S FUTURE: AN ASSESSMENT OF PROSPECTS AND IMPACTS

Final Report

January 1980

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Office of Transportation Programs
Department of Energy
Washington, D. C.

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Report No. 97

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WHY ARE U.S. RAILROADS NOT ELECTRIFIED?

In Europe, and throughout the world, electricity supply by overhead wires powers the locomotives that pull freight trains. In the United States, however, freight trains are powered by diesel-electric locomotives. These differing motive powers are attributable, in the main, to the conditions that prevailed immediately following World War II. Petroleum-poor European countries, faced with refurbishing their war-worn railroads, chose electric motive power because a diversity of primary energy sources could be used to generate electricity, including the hydropower that some countries possessed in abundance. Moreover, the relatively short but heavily used rail lines in Europe yielded a better return on investment for capital-intensive electrification facilities than could be expected from the longer, more lightly traveled rail lines in the United States.

ARE THERE ADVANTAGES TO ELECTRIFICATION?

U.S. railroads have shown some interest in electrification because the price of diesel fuel is expected to escalate more rapidly than the price of electricity and because electric locomotives require less maintenance. Moreover, electric locomotives can draw more than their rated continuous power for short periods; they can thus climb grades without having to reduce speed so much as diesel-electrics do, thereby effectively increasing the capacity of existing track. The federal government is interested in electrification because it would help reduce U.S. reliance on foreign petroleum.

WHAT WOULD ELECTRIFICATION ENTAIL?

Electrifying U.S. railroads would require stringing high voltage (25-kV or 50-kV) wires above the tracks, improving the clearance in tunnels and bridges, reworking the signaling and communications systems to avoid electrical interference, and purchasing or leasing new electric locomotives instead of diesels. The classifying yards where trains are assembled would not be electrified, but would serve as natural endpoints for electrified sections of mainlines. In general, branch lines would not be electrified because their low use would not warrant the high capital costs involved. Indeed, it would be economically feasible to electrify only the most heavily used mainlines.

HOW MUCH ELECTRIFICATION MIGHT BE FEASIBLE AND WHEN?

Taking into account such considerations as the level of traffic, the relative financial health of individual railroads, the capacity of the associated supply and engineering/construction industries, and the logical connecting points at classifying yards, as well as the national interest value of creating a continuous system, continental in scope, we constructed a scenario for railroad electrification that closely approximates how an electrification program might be implemented. For the economic reasons cited, much of the U.S. railroad system would remain conventionally powered. This scenario provides for an electrified network involving 14 mainlines operated by 10 companies that could transport much of the nation's rail-borne freight. Five years of planning and engineering work would be required for each link before construction could begin. With 1,000 miles or less of electrified route per year, 14 years would be needed to construct the 9,000-mile network of our scenario. (The scenario we constructed thus runs from 1980 to 1998.)

WHAT WOULD BE THE CONSEQUENCES OF ELECTRIFICATION?

The operations of electrified and conventional railroads are quite similar. As a result, relatively few overall impacts would be felt by railroad employees (mainly a shift in some job skill requirements). In addition, inhabitants near the tracks would be affected beneficially with less noise and better air quality. The total power required for the complete network could be provided by about 2000 MW of generating capacity.

The most significant impacts by far would be on the finances of the implementing railroads. Because many U.S. railroads are now in poor financial health, we carefully assessed whether railroads could withstand the economic strain of electrification, and, if they could, whether electrification would be sufficiently profitable to be attractive to railroads. (Although 10 or more railroads have seriously studied electrification, none has announced firm intentions to electrify.)

To aid our analysis, we constructed the SRI Railroad Industry Model. Basically a model of industry operations and finances, the model produces income statements and balance sheets at yearly intervals. To obtain these financial statements, we calculated railroad energy costs, railroad freight levels, maintenance costs, purchases and leases of rolling stock, electrification facility investments, future inflation, rate setting practices, annual depreciation, taxes, and profits. We first made sure that our model gave reliable results by using it to reproduce historical records. Then we applied it to our electrification scenario in two ways. We first treated the 14 mainlines as if they were operated by one composite company, which was then assumed to pursue our scenario. We then analyzed one of the actual implementing companies—the Santa Fe—to learn how the composite company results might differ from the impacts an individual company

might experience. Finally, we varied many of our assumptions about the future to learn how sensitive the conclusions were to each assumption.

Because railroads set their freight rates under the supervision of the Interstate Commerce Commission on what has amounted to an operating cost-plus basis, we found that if that practice were continued, the operating cost savings made possible by electrification would slightly reduce the consumers' average freight rates, rather than being realized as increased profits for the electrified railroad. The slightly lower rates would, however, slightly increase the demand for the railroad's freight service.

Although operating costs would be reduced by electrification because locomotive maintenance and energy expense would be lowered, those two expenses combined amount to only about 15% of the total operating costs, and, therefore, do not have much leverage. The lower energy expenses reflect the relative prices of diesel fuel and electricity. Overall energy efficiency is nearly the same with either locomotive. However, if the alternative to electrification is synthetic oil derived from coal, the overall energy efficiency of railroad freight transportation is improved by an impressive 50% or so for electrified lines. If the links in our scenario were all electrified, the U.S. could reduce oil consumption by about a billion gallons per year--about 1% of the mid-1978 import rate.

Useful as this potential oil saving may appear for the nation, from an implementing railroad's point of view, the picture does not appear so rosy as long as freight rates are set on an operating cost-plus basis. In fact, the railroad would require substantial extra capital that, given the railroad's prospect for return on the investment, would be extremely difficult to obtain in equity or bond markets. Even with federal guarantees on debt, both funded debt and equipment debt

(secured by a lien on the rolling stock financed) would increase substantially. Higher interest payments, lower earnings, and a significant erosion of the rate of return on total investment or equity in the railroad would result.

Worthy of note is the relative magnitude of the extra capital required for electrification above and beyond that required to finance the rolling stock, which must be purchased in any event because of the slow but steady increase in traffic that is expected, as well as normal retirements. Even during the period of most intense spending for electrification structures, the investment rate in these structures would be only about one-third to one-half that required for new rolling stock of all kinds. Although that observation places the added outlays in perspective, electrification is nonetheless likely to be viewed cautiously by most railroad managements.

Our analysis of alternative assumptions clearly indicates, however, that the United States could indeed realize petroleum saving by railroad electrification. The most important institutional change that would stimulate electrification is a change in the basis on which railroad rates are found acceptable by the Interstate Commerce Commission. The present practice of operating cost-plus rate-setting deters electrification because the railroad cannot retain operating costs savings to offset the costs of acquiring additional capital. If, instead, a fixed rate of return on total invested capital were the basis, the substantial funds needed for electrification would not result in adverse profitability for the implementing railroads. Indeed, under this approach to rate setting (used in the regulation of electric utilities and telephone companies—two other capital-intensive industries), railroads could finance more of the investment from retained earnings and, therefore, would have to seek less external financing. This advantage is not gained without a cost, however; this cost is manifested in slightly higher freight rates.

Several other approaches can be taken to mitigate adverse financial impacts on the implementing railroads. One is for the railroads to charge users for hauling freight as if the line were not electrified at all, by simply charging the rate that would have been appropriate had the railroad continued diesel-electric operations. This approach would let the railroad keep the operating savings electrification generated. We have reason to doubt, however, that the regulators would countenance this rate-setting approach for long. Government ownership of the fixed electrification facilities, with an arrangement for joint use between the host railroad and other railroads serving the same corridor would, of course, remove the burden of financing from the railroads and shift it to the government. Under these conditions the financial impacts on the implementing railroads would be minimal.

Variations in our assumptions about rate-setting proved much more potent in altering the impacts than variations in our assumptions about the rate of inflation (and the accompanying variation in interest rates), debt versus equity financing, or investment tax credits.

ARE WE LIKELY TO HAVE ELECTRIFICATION?

From our analysis of the impacts of railroad electrification and the barriers those impacts pose, we conclude that few, if any, railroads are likely to embark on electrification under the present regulatory climate of rate-setting. Should the regulators adopt the return-on-investment concept as now applied to other regulated industries, the prospects for the railroads' undertaking electrification on their own initiative look much more promising. If the government were to underwrite the fixed investment costs of electrification as an investment that results in a petroleum-saving, the prospects also are much better.

Although we did not analyze the situation of complete deregulation, it too, might possibly improve the prospects for electrification. Since the time our analysis began, world oil prices have risen much more than was forecast. As a result, the operating savings to be gained from the differential cost in electricity and diesel fuel have increased. This naturally improves the attractiveness of electrification.

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I INTRODUCTION

Why Assess Electrification?

U.S. railroads have steadily turned away from electrified operations in favor of using diesel-electric locomotives. Before World War II electrified railroads in the United States accounted for 6,500 track miles; now, however, there are only 1,162 electrified route miles (FRA, 1977)*. Only two wholly new electrified lines have been built in recent years—the Muskingum Electric Line (15 route miles) and the 78-mile Black Mesa and Lake Powell coal hauling line.

Interestingly, the decline in railroad electrification in the United States began to occur as European railroads became increasingly electrified. Several reasons explain these opposing trends on opposite sides of the Atlantic. First, immediately following World War II many European countries had to rebuild or refurbish their devastated or overtaxed railroads. When choosing a form of motive power, it was natural for the petroleum-poor countries of Europe to favor relatively inexpensive electric power over the new diesel-electric technology, especially where hydroelectric power was available. Meanwhile, the opposite motivation prompted the United States, which was then rich in petroleum, but where hydroelectric power was generally unavailable. Second, because railroad electrification is capital-intensive, the denser, more heavily used European routes would give superior returns on capital invested in electrification than the longer distance, relatively lightly used U.S. rail network. Third, the nationalization of European rail operations offered an organizational setting that facilitated railroad electrification, whereas in the United States, many competing and interconnecting railroads would have to coordinate investments to achieve a workable electrified network.

*References are collected at the end of the report (page 139).

As attention in the United States has increasingly been drawn to the plight of our nation's railroads--stimulated by the notoriety of bankruptcies in the Northeast--electrification has received more prominence. Indeed, in the Railroad Revitalization and Regulatory Reform Act of 1976 (the 4R Act) Congress required that the Federal Railroad Administration examine the desirability of electrifying portions of the U.S. rail network, and authorized up to \$200 million in loan guarantees for electrification of Conrail lines between Harrisburg and Pittsburgh, Pennsylvania.

This new interest derives from two suppositions: First, electrified railroads are said to be generally more efficient and reliable. Second, railroad electrification might lessen the U.S. need for oil (nearly half of which is imported) because electricity could be generated from coal, nuclear, or other nonpetroleum energy resources. Thus, if these two suppositions are true, advantage should be taken of them if and when U.S. railroads are refurbished.

The Transportation Energy Conservation Division of the U.S. Department of Energy commissioned SRI International to examine the consequences of railroad electrification. Can overall energy or, especially, petroleum be saved by these means? If so, how much and how soon? At what expense and with what side effects? This report summarizes SRI's investigations into these questions, investigations that have included obtaining opinions and data from railroads, labor, equipment manufacturers, electric utilities, federal and state governments, and other parties at interest in a 2-day workshop at which we presented and discussed our preliminary findings.

As we address the questions posed above, the reader will see that electrification will most affect the finances of railroads being electrified, adversely under certain common assumptions. It will thus become apparent why none of the 10 or so railroads that have seriously considered electrification has yet decided to proceed with it. However, the reader will also see that several potential federal policies could change the railroads' economic climate sufficiently to make electrification much more attractive, and may induce railroads to electrify.

II ELECTRIFIED RAIL TRANSPORTATION —

What is It?

This chapter describes technical aspects of railway electrification so that those unacquainted with railroads or electrification can read the remaining chapters of this report without frequent recourse to technical references.

First, railroads are discussed in the context of the modes of freight transportation available in the United States. Then, equipment and facility differences between diesel-electric and electric operation are described, and how those differences affect train operations are pointed out. Capital and operating costs are next considered and the energy uses of both types of locomotive operation are compared.

Freight Transportation

Besides railroads, the major modes of U.S. freight transportation consist of trucks, inland and coastal waterways, pipelines, and aircraft. The percentage distribution of intercity freight ton-miles by mode in 1975 was (DoC, 1977):

Railroads	36.4
Trucks	23.5
Inland and coastal waterways	16.5
Oil Pipelines	23.5
Aircraft	<u>0.2</u>
	100.0

The tabulation shows that railroads carry more freight farther than any other mode. Freight is frequently classified in terms of the value of the shipment per unit volume. Low-valued materials, such as bulk commodities, coal, ore, and grain, comprise about 64% of railroad freight. Medium-valued commodities, for example most manufactured goods, comprise most of the remainder. The residual is high-valued freight, such as computers and high-fashion apparel, as well as other highly manufactured goods, which are infrequently shipped by rail. We consider these three commodity classes separately in this study.

Trucks compete for high-value commodities and, as trailers on flatcars (TOFC), comprise a medium-value commodity for the railroads. Highway trucks are more versatile than any other carrier because virtually any terminus of the other modes can be served by trucks, in addition to a limitless number of other destinations. Moreover, trucks can generally move goods faster than can railroads; however, truck cargo capacities are limited.

Barges and ships compete with railroads in all three commodity classes. The cost of waterway transportation is generally sufficiently cheaper on a ton-mile basis that, if relatively direct service is available and if cost is the dominating criterion for selection, a waterway is selected instead of a railroad. If the route is indirect or if intermodal service is needed, a railroad may be selected for part or all of the service.

Pipelines are used for bulk commodities such as oil or slurried coal. Pipeline transportation is so inexpensive and reliable that, if sufficient demand exists between two points, other modes cannot compete successfully. Other factors, however, such as the duration of transportation need and the availability of water for coal slurry, may point to other modes.

Aircraft carry high-value commodities at relatively high freight rates where delivery time and, in some cases, security are important criteria. Although other transportation modes do not compete as effectively for this type of cargo, and the volume, as shown in the tabulation, is quite small in relation to all freight transported.

The Interstate Commerce Commission (ICC) actively fosters competition among railroads through regulations that interstate carriers must observe. In particular, the ICC requires that at least two independent railroads serve major market regions. Thus, a railroad company generally faces both intermodal and intramodal competition.

Equipment and Facilities

The distinction between diesel-electric and electric railroad operation begins with the locomotive. The diesel-electric locomotive carries its own motive power and fuel supply. A typical installation in a line-haul locomotive would be a 16-cylinder diesel engine, possibly turbocharged, that drives an alternator (ac generator). The alternator output is rectified in solid-state electric power-conditioning equipment, and direct current (dc) is fed to electric traction motors driving each axle. Because locomotives, as a practical matter, are limited in size and weight, carrying the motive power supply limits the typical six-axle line-haul locomotive to equivalent power of about 3000 kW. (Yard locomotives, many of which have four axles, are usually smaller.) To meet a demand for more power to pull long trains or to negotiate steep gradients, multiple locomotives are linked together in a locomotive "consist" at the head of the train.

Electric locomotives, on the other hand, derive their power from electricity generated at a central station. The diesel engine and alternator are replaced by a transformer that steps down the line voltage to a level acceptable to the power conditioning equipment. That equipment, the traction motors, and other ancillary equipment resemble corresponding equipment on the diesel-electric. However, an electric locomotive of the same size and weight as a diesel-electric has a continuous power rating that is far higher—a range of 5200 to 6000 kW can be achieved, for example. Furthermore, the continuous power rating of an electric locomotive can be significantly exceeded for periods that are limited only by the buildup of heat in the equipment. This practice frequently allows the assignment of a locomotive consist that is lower in continuous power rating than a

diesel-electric locomotive consist would be, but that still allows the maximum grade encountered to be negotiated without unacceptable delay. Overall, when electric locomotives are substituted for diesel-electric in the average locomotive consist, only about half the number of locomotives may be required. The size of the fleet of electric locomotives required to replace diesel-electric service can be even somewhat further reduced because electric locomotives are available for service more of the time. Diesel-electrics require more maintenance (e.g., engine maintenance and refueling requirements), and have special requirements in extremely cold weather (e.g., cold-weather starting).

The most significant change in equipment and facilities for railroad electrification, other than the change in locomotives, is providing central station electric power. The long history of electric traction in the United States and other countries has witnessed a great variety of distribution systems--both alternating and direct current supply; voltages ranging from a few hundred volts to 50 kV; alternating current supplied at both commercial and noncommercial frequencies; and the use both of "third rails" and of overhead wires, termed "catenaries." The technical reasons for selecting various systems may interest many readers, but are not appropriate to the needs of this study. Friedlander (1968) gives a good guide to that history, and to related references. Instead, we describe briefly the components of a modern scheme for U.S. line-haul freight electrification.

Power is supplied to the electric locomotive from a catenary suspended approximately 23 ft directly over the tracks (see Figure 1). The locomotive picks up the current with a pantograph, an articulated structure mounted on top of the locomotive (see Figure 2). The return current flows through the rails. Other than the pantograph, the electric locomotive outwardly resembles the diesel-electric. The catenary in turn is supplied current at 25 or 50 kV from substations spaced along the right-of-way at about 20-mile intervals with the 25-kV system, and at about 40-mile intervals with the 50-kV system. Although the higher voltage may be preferred because of its typically lower cost, greater clearance is required in tunnels and on bridges for adequate electrical insulation. Those factors may lead

FIGURE 1. OVERHEAD CATENARY THAT SUPPLIES POWER TO ELECTRIC LOCOMOTIVES

FIGURE 2. OVERHEAD CATENARY SUPPLYING POWER TO ELECTRIC LOCOMOTIVE BY MEANS OF A PANTOGRAPH

to a choice of the lower voltage, at least on some routes. It is also feasible to employ both voltage supplies on alternate line segments, because a hybrid locomotive costs only nominally more—perhaps 3%. Finally, the substations are supplied by transmission lines from the central power plant, at a variety of voltages that depend on location and distance.

Electrification of the track necessitates changes in other railroad systems, principally in the signaling systems and in some cases the communication systems. Conventional signal systems use the rails to determine the presence of a train in well-defined "blocks" along the tracks. The steel axle and wheels of a locomotive or freight car makes electrical contact with both rails, completing a dc circuit that signals the presence of a train in the block. The use of the rails as a return line for load current to the substation is incompatible with this form of signal system. Consequently, more elaborate signaling equipment must be used when tracks are electrified. Ordinarily, that equipment is installed at the same time the track is electrified.

Railroads use extensive communications systems that commonly are deployed along the right-of-way of the track. These systems may suffer interference from two sources: induction from the electrostatic or electromagnetic fields created by the catenary and rails; and both line interference to the system power supply and radiofrequency interference caused by the power-conditioning equipment in the locomotive. Consequently, more elaborate equipment is commonly required to ensure reliable communication in the electrically noisy environment; this equipment is also ordinarily installed when track electrification is undertaken.

Other changes in facilities include less capacity required for diesel engine maintenance (some is still required for yard locomotives, which are not affected by the electrification of mainlines), and increased maintenance capacity for electrical equipment. Finally, civil reconstruction is required when tunnels and bridges or other structures do not allow adequate clearance for the catenary.

Operations

Diesel-electric and electric locomotion characteristics lead to operational differences that must be considered in evaluating the effects of electrification on a line now operated with diesel locomotives. Those differences have been well established by the experience of American and foreign lines (Friedlander, 1968; Ross, 1971; Schwarm, 1976). They can be summarized as follows:

- o The higher power per axle for electric locomotives allows fewer locomotives per consist to yield the same performance in load and speed.
- o The overload capacity available with the electric locomotive results in shorter locomotive consists or shorter running times, or both.
- o Because it requires less maintenance and no refueling, the electric locomotive is more reliable and more available for use, thereby reducing the need for standby locomotives.
- o Because advanced adhesion control equipment is more effective with the electric locomotive, the tractive effort per axle and, hence, per locomotive is further increased.
- o Track capacity and throughput can be increased with electric operation because of the improved acceleration and reduced running times.
- o The effluent and noise associated with the diesel engine are eliminated with electric operation, but the average noise level near the track may increase if the speed or length, or the frequency of trains is increased.
- o Flexibility is lost with the electric locomotive, which cannot operate on nonelectrified mainlines, branch lines, sidings, or yards.
- o When derailments occur, they often damage the catenary, which must be repaired to restore service.
- o The high-voltage wiring may present a greater occupational and public hazard than the handling and use of diesel fuel.
- o Given the longer maintenance intervals and lack of refueling constraints, longer train runs are functionally possible, but the runs are limited by work rules in labor contracts.
- o Regenerative braking with electric locomotives offers energy conservation potential, if technical and institutional problems of feeding the power back into the grid can be resolved.

Costs

The costs that we assumed for locomotives, for track and other facilities, for the civil reconstruction, and for operating expenses are listed in detail in Appendix A. Here we summarize some of the cost considerations, and indicate how the capital costs and operating costs are related.

Locomotive capital costs are essentially the same for either diesel-electric or electric operation. The greater power and availability of the electric locomotive is almost exactly offset by its higher unit cost.

The capital cost for the track electrification facilities—catenary, substations, and signal and communications gear—totals approximately \$160,000 per track mile for a single track route. The cost of civil reconstruction ranges from about \$5,000 to about \$50,000 per route mile.

With sufficient volume of traffic, the common expectation is that the reduced operating costs assumed with electrification will more than offset the added capital costs. The principal anticipated source of reduced operating cost is energy, because the price of diesel fuel is expected to increase faster than the price of electricity. A less important source of reduced operating costs is locomotive maintenance—the cost for electric locomotives is expected to be approximately 40% of that for diesel-electric locomotives employed in the same service.

The capital costs for the electrification of facilities, including civil reconstruction, are often portrayed as a staggering and unprecedented burden on railroads, especially in view of other demands for capital to replace or restore track and other facilities. However, we find that the demand for capital for purchase of rolling stock, including both freight cars and locomotives, exceeds the capital demand for electrification of facilities by a factor of at least 2 over the period of conversion to electric power.

(This observation assumes that the historic ratio of leased to owned rolling stock is maintained.) Consequently, although electrification demands significant capital, this demand is far exceeded by that for rolling stock, which must be bought regardless of the decision to electrify.

Energy Use

The overall efficiency in the use of fuel to produce one unit of transportation (i.e., a ton-mile) is essentially the same, whether the combustion takes place on board the locomotive or at a distant central power station. Higher central station efficiency is offset, on average, by increased transmission losses. Hence, electrification is not normally promoted to conserve energy. However, this situation would change if diesel fuel had to be derived from synthetic crude oil, made from coal. In this case, the energy lost in the conversion from coal would greatly diminish the overall efficiency of diesel operation when compared with electricity generated in a coal-fired central plant.

The principal energy benefit in railroad electrification derives from the potential switch from petroleum as a resource base, viewed as a demand for foreign energy, to a domestic coal or nuclear resource base. However, railroad use constitutes a small part, less than 2%, of U.S. petroleum use. Hence, encouraging the allocation of capital to railroads to reduce petroleum use should be carefully compared with encouraging alternative uses of that capital to achieve the same end.

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III WHO ARE THE STAKEHOLDERS?

What are Their Stakes?

Using the description of the physical, technical, and financial aspects of the electrification of mainline railway as a guide, we turn to the consideration of the parties affected by electrification. Those who have a stake in electrification we call stakeholders. They can be grouped into eight classes:

- o The public
- o Transportation users
- o The carriers
- o Equipment and materials suppliers
- o Labor
- o Electric utilities
- o Financial institutions
- o Governmental bodies

We describe and define each class along with an indication of the nature of the party's stake. We also indicate the interactions of each class with other stakeholders, and we discuss past activities that may relate to the decision to electrify.

The Public

The "public" includes everyone in the United States. However, it is useful to focus on public attributes that relate to anticipated impacts. Hence, we consider people as consumers of goods and services, as taxpayers, as property owners along right-of-way, and as highway users.

Nature of the Stake

Consumers are ultimately affected by the cost and quality (speed of service, damage, losses) of transportation service, and the availability of fuels and electricity. Taxpayers are indirectly affected by the property and income taxes the railroads pay, and by federal decisions to subsidize electrification through grants, low-interest loans, or the like. Property owners along the right-of-way are affected by air pollutants emitted by passing trains, noise, electromagnetic interference, the aesthetic quality of railroad property, and property taxes. Highway users are affected by delays at railroad grade crossings, safety of the crossings, air pollution in the vicinity of crossings, and the density of trucks on highways. All citizens are concerned with the vitality of the railroads as an aspect of national economic well-being and national defense.

Interactions

Members of the public interact with governmental bodies when they perceive that their interests are at stake. Acting as individuals or through organized advocacy groups, the public may take its case to members of Congress, to local governments, or to regulatory bodies. Consumers interact with freight shippers and their customers when they purchase goods or services that contain imbedded transportation costs.

Past Activities

The public has not been particularly active on issues related to the electrification of mainline freight transportation, probably because the prospect has not appeared imminent.

Transportation Users

Direct users of freight transportation include shippers and their customers. The users on either the sending or receiving end, contract directly with

the carriers. The same party may be involved at both ends (e.g., a manufacturer may ship goods-in-process).

Nature of the Stake

Users have a direct interest in the cost of transportation and the quality of service, including the speed of shipment, the frequency and reliability of service, and the security of the shipment.

Interactions

Users interact with carriers in contracting for transportation, and with members of the public who consume the users goods and services. Users also lobby and testify before governmental bodies, when legislation or regulations affecting transportation are under consideration. Such interaction may be carried out by representatives of individual users or of user trade groups.

Past Activities

Users have not been particularly active on issues related to electrification, probably because the prospect has not appeared imminent.

The Carriers

This class includes the railroad companies, both those that operate mainline links which are assumed to be electrified in the scenario in the following chapter and operators of railroad links that would compete with the electrified ones; trucking companies; barge operators; pipeline operators; and airlines.

Nature of the Stake

The carriers have a vital financial stake in railway electrification, including such aspects as capital financing arrangements, federal subsidies, market share, and freight rate structures. Efficiency of operations and reliability of energy supply are also concerns. The railroad electrifying a mainline has the greatest stake, followed by competing railroads, and then by other competing carriers.

Interactions

Carriers interact with transportation users in contracting for transportation and with suppliers in purchasing the equipment and materials needed to maintain, operate, and expand capital equipment and other assets, including electrification facilities. Carriers interact with labor in setting wage rates, work rules, and other conditions of employment, and with electric utilities in contracting for electricity needed to operate electrified mainlines. Financial institutions and carriers interact when stocks, bonds, or other financial instruments are needed to provide funds for capital expenditures. Carriers interact with governmental bodies when they testify and lobby, and when they provide information used to judge rate requests, proposals to extend or abandon service, proposed mergers or acquisitions, and the like. Carriers also interact with governmental bodies indirectly, through trade groups.

Past Activities

Several railroad companies, including Southern Pacific, Santa Fe, Southern, Illinois Central Gulf, and Burlington Northern, have considered the electrification of certain mainlines; however, they are not proceeding at this time. A Conrail line from Harrisburg to Pittsburgh is in an advanced planning stage for electrification.

Equipment and Materials Suppliers

This class includes locomotive and freight car manufacturers and leasing organizations, electrical and mechanical equipment manufacturers, fuel oil suppliers, manufacturers and suppliers of transportation equipment for modes other than rail, and construction firms.

Nature of the Stake

Suppliers have a financial interest in the types and quantities of transportation equipment manufactured; for example, whether the motive power is diesel-electric or electric and whether the market shifts toward more rail transportation are concerns of interest to these stakeholders.

Interactions

Suppliers interact with carriers in selling them the equipment and materials needed to maintain, operate, and expand their capital equipment and other assets. Suppliers also interact with labor in setting wage rates and other conditions of employment.

Past Activities

Past activities have been largely confined to the two major locomotive manufacturers in the United States—General Motors (GM) and General Electric (GE). GM manufactures diesel-electric locomotives and makes electric locomotives under license from ASEA in Sweden; its diesel-electrics dominate the U.S. market for locomotives (about 75% of the market). GM has shown little enthusiasm for a market shift to electric locomotives. On the other hand, GE, with a longer history of electric locomotive manufacture, appears enthusiastic about a potential market shift away from diesel-electrics, a market in which it

has gained only about a 25% share. Two coal-hauling lines, the Muskingum (15 miles) and the Black Mesa and Lake Powell (78 miles), have been built recently as electrified lines and employ modern technology.

Labor

This class includes wage earners in construction, maintenance, and operations roles employed by suppliers and by the carriers.

Nature of the Stake

Labor has a direct interest in the wages paid and other conditions of employment, such as job security, work rules, skills mix, job safety, and relocation.

Interactions

Labor interacts with both carriers and suppliers in negotiating wage rates and other conditions of employment. Labor also interacts with governmental bodies, usually through group associations, in presenting testimony and in lobbying when the interests of labor are involved.

Past Activities

Labor has not been very active on issues related to electrification, probably because the prospect has not seemed imminent.

Electric Utilities

This class includes the public utilities that would supply electricity to electrified mainlines in the United States.

Nature of the Stake

The utilities have an interest in the cost of providing electrical service and in the rates that would be charged. The size of the load relative to other service in the area, load variation with time, and technical features of the load (e.g., current waveform, phase loading) that could affect service to other customers are also concerns.

Interactions

Utilities interact with carriers in negotiating the provision and price of service, and with governmental bodies in obtaining approval of proposed rate structures for electricity.

Past Activities

Utilities have not been particularly active recently in regard to railroad electrification, other than their limited study of the effects of the locomotive load on the distribution system. Earlier, when electricity use was actively promoted generally, some utilities offered to share a portion of the installation costs of the new transmission lines required.

Financial Institutions

Financial institutions include participants in the market for securities--stocks, bonds, notes, and other commercial paper created by the carriers.

Nature of the Stake

Financial institutions have a direct financial interest in the profitability and general financial health of publicly owned carriers.

Interactions

Financial institutions interact with the carriers whenever financial instruments are exchanged for the cash needed for capital investment. Financial institutions interact with governmental bodies that regulate the issuance of securities, the terms and conditions of loans (e.g., maximum interest rate), the trading (liquidity) of securities, and the money supply, which affects the availability and cost of capital.

Past Activities

Financial institutions have not been very active in regard to railroad electrification, which they view only in the context of investment potential.

Governmental Bodies

Governmental bodies include the federal government (Congress, the Departments of Energy, Transportation, Commerce, Labor, and Treasury, the Environmental Protection Agency, and the Interstate Commerce Commission), and state and local agencies (public utilities commissions; air quality control boards, highway safety agencies, and taxing authorities).

Nature of the Stake

Governmental bodies manifest essentially all interests that other stakeholder classes hold, plus interests on behalf of the nation as a whole. Examples are maintaining national security in the event of a major mobilization of forces, reducing the importation of petroleum products and its effect on the trade and balance of payments accounts, protecting the environment; ensuring tax revenues, and maintaining the financial health and energy efficiency of the transportation system.

Interactions

Governmental bodies interact with the public, users, carriers, labor, utilities, and financial institutions in obtaining information related to their well-being under proposed and existing laws and regulations, in enforcing laws and regulations, and in promulgating new ones.

Past Activities

The most significant recent activity related to electrification was the passage of the Railroad Revitalization and Regulatory Reform Act of 1976 (4R Act). Among other provisions related generally to railroads, the act called for a study of railway electrification. In addition, funds were made available through a system of loan guarantees to improve railroad assets, including electrification.

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IV WHEN MIGHT WE HAVE ELECTRIFICATION?

How Much, How Fast?

The stakeholders and stakes in railroad electrification have just been described. Drawing on this information and on technical considerations of Chapter II as a backdrop, we now consider a scenario of electrification that will enable us to quantify and analyze further impacts on the vested interests of stakeholders. There are several reasons for developing a detailed scenario, with specified mainlines and dates for conversion:

- o Concrete analysis contains fewer generalizations, directly relates to stakeholders by citing particular railroads, and is more quantitative.
- o The development of rational selection criteria for candidate railroad links imposes a greater degree of realism in the results. Although the scenario should not be viewed as a forecast of where and when electrification will actually occur, it is a plausible sequence of events that resembles the order and rate of electrification were it to begin. Implicitly, for a scenario such as this to occur, favorable economic, political, institutional, and governmental climates would have to exist to make electrification of railroads attractive throughout the scenario period.
- o The development of rational timing criteria for conversion of the selected links ensures that the results deduced from using the scenario are relatively consistent with various real-world constraints, such as a maximum rate for track conversion.
- o A detailed scenario is necessary for use with our new systems dynamic computer model of the railroad industry described in the following chapter, that will enable us quantitatively to find internally consistent sets of consequences for the various stakeholders.

Selection Criteria for Candidate Railroad Links

In building our scenario, we considered the following basic aspects of electrification and of railroad operation:

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- o High traffic volume spreads the fixed costs of electrification over more tons of freight than would lower traffic, thereby reducing unit transportation cost (up to the limit of track capacity). From this we conclude that the highest traffic density mainlines would electrify earlier (other considerations being equal), and that low traffic density mainlines or branchlines would not be electrified.
- o Only high-density freight traffic would be considered. Passenger traffic was not considered because it constitutes such a small portion of U.S. rail operations.
- o Because of inefficiencies in changing types of locomotive consist en route, we assume that electrified routes must terminate in major freight classification yards at both ends.
- o Because the slight advantages of electrifying yards are not justified by the added cost, we assume that no yards are electrified.
- o Although most major market regions are connected by at least two lines, and some are connected by several, we assume that only one, usually the financially strongest, will be electrified.
- o Because of the limited capacity in the required support industries that design, construct, manufacture, and install the equipment and facilities needed for electrification, we assume that no more than about 1000 miles of new facilities will be installed per year.
- o Because of the favorable economics that result from continuity of electrification along a route, we stressed the building of electrified facilities in an order that extends the system already built.
- o System comprehensiveness would be considered. Development of a transcontinental electrified railway network would have priority.

These criteria amount to a set of assumptions regarding the constraints under which electrification of mainline freight transportation would most likely proceed. The economics of electrification and operational considerations underlie these criteria. But the last criterion, system comprehensiveness, is more arbitrary than the others. Its inclusion is consistent more with potential national needs or goals than with likely economic or operational constraints. However, in building the scenario none of the other criteria was significantly violated to accommodate system comprehensiveness as a criterion.

Timing Criteria for Candidate Railroad Links

The following timing criteria were used to determine when a selected candidate link would be electrified:

- (1) Less than 1,000 miles per year of mainline track could be electrified.
- (2) The relative levels and growth of traffic would be used for ranking the candidate links (at the time of building the scenario, 1974 data were the latest available).
- (3) Delays would be allowed to accommodate planning and decision making.
- (4) The financial health of the railroad company operating the candidate link would be considered.
- (5) Electrified system continuity would be considered for timing, as well as for link selection.

These timing criteria, like the selection criteria, amount to a set of plausible assumptions regarding constraints. The limitation on new electrified trackage in a year relates to constraints on the capacity of the sector of the economy that supplies engineering, materials and equipment, and construction services. Criteria (3) through (5) were used to adjust a ranking developed solely on the basis of traffic under criterion (2).

Development of the Electrification Scenario

The electrified railroad network resulting from the use of the selection criteria is shown in Figure 3. Table 1 lists the names of the operating companies for each link electrified and the year of initial electrified operation resulting from the use of the timing criteria.

Now, each link will be discussed briefly. The first date given with each railroad company link indicates when the decision is made to electrify the specified link and the second date indicates when the electrification of facilities is completed and electric locomotives go into service.

* See Table 1 for identification of links.

FIGURE 3. SCENARIO OF RAILWAY ELECTRIFICATION BY LINK*

Table 1

RAILROAD LINKS IN THE SCENARIO AND
DATES ELECTRIFIED OPERATION STARTS

<u>Link Number</u>	<u>Operating Railroad</u>	<u>Starting Date</u>
1	Southern Pacific	1985
2	Santa Fe	1986
3	Union Pacific	1987
4	Chicago and Northwestern	1988
5	Conrail	1989
6	Burlington Northern	1990
7	Southern Pacific	1991
8	Santa Fe	1992
9	Norfolk and Western	1993
10	Chessie System	1994
11	Chessie System	1995
12	Chessie System/Southern	1996
13	Norfolk and Western	1997
14	Illinois Central Gulf	1998

Link 1: Southern Pacific, 1980-1985

This 750-mile route runs from Colton, California to El Paso, Texas. Approximately 40 million gross tons (mgt) were hauled on the link in 1974. It is currently single track, and the company would like to add capacity. However, the traffic growth expected would not make a second track a sufficiently attractive investment to proceed. Electrification, in this case, therefore, has the added attraction of allowing increased levels of traffic without incurring the expense of adding another track. This link was even more attractive to the company when the company was considering the purchase of the Rock Island line from Tucumcari (served though El Paso on the west), New Mexico, to Kansas City, Missouri.

Link 2: Santa Fe, 1981-1986

This 968-mile link runs from Barstow (near Colton), California, to Clovis, New Mexico. About 40 mgt were carried on the link in 1974. Because this is a double track, high-speed route, electrification of this link would offer a maximal return on investment.

Link 3: Union Pacific, 1982-1987

This 992-mile link runs from Council Bluffs, Iowa, to Salt Lake City, Utah. Approximately 35 mgt were hauled on the link in 1974. This link is an attractive candidate for electrification because it comprises a long segment over which traffic passes with little diversion. Because this link has few branch lines, which are not electrified in the scenario, the advantages of electrifying the mainline are relatively undiluted.

Link 4: Chicago and Northwestern, 1983-1988

This 163-mile route runs from Chicago, Illinois, to Omaha, Nebraska (across the Missouri River from the Council Bluffs terminus of the Union Pacific link). About 45 mgt were carried on this link in 1974. This link and the two that follow are about equally attractive. Besides connecting with the Union Pacific link, this link allows consolidation of traffic among several lines in this corridor. The joint track agreement between the Rock Island Line and the Milwaukee Road serves as a precedent for such consolidation.

Link 5: Conrail, 1984-1989

This 825-mile link runs from Chicago, Illinois, to Selkirk, New York. Approximately 74 mgt were hauled on this link in 1974. This link connects with the Chicago and Northwestern link, and comprises the main spine of the eastern part of the electrified network. It ranks behind the western routes largely because of higher electricity costs in the eastern part of the country.

Link 6: Burlington Northern, 1985-1990

This 366-mile link extends from Lincoln, Nebraska, to Alliance, Nebraska, and intersects with the Union Pacific link. Although only 15 mgt were carried on this link in 1974, a large increase in coal traffic is expected. The possibility of extending the electrification from Alliance to Gillette, Wyoming (center of the coal-rich Powder River Basin) has been discussed; that extension, however, is not included in the scenario.

Link 7: Southern Pacific, 1986-1991

This 705-mile link, extending from Ogden (near Salt Lake City), Utah, to Roseville, California, completes the first transcontinental corridor; it carried 35 mgt in 1974. Because of extensive overhead clearance problems in tunnels and snowsheds in California's Sierra Nevada Mountains, the link would rank lower if it did not connect with the Union Pacific, Chicago and Northwestern, and Conrail links.

Link 8: Sante Fe, 1987-1992

This 1085-mile link runs from Chicago, Illinois, to Clovis, New Mexico. The traffic on the link totaled about 40 mgt in 1974. This link connects with the Chicago and Northwestern and the Conrail links in Chicago and with the other Santa Fe link at Clovis, New Mexico, thereby completing a second transcontinental electrified route. Competition is a significant factor here, both with the first transcontinental route electrified and with the Southern Pacific route in the south.

Link 9: Norfolk and Western, 1988-1993

This 548-mile link runs from Roanoke, Virginia, to Bellevue, Ohio, and is located near the Conrail link. This link, a heavy coal-hauling route, carried 40 mgt in 1974, and would have ranked higher except for the higher cost of electricity in the eastern part of the country.

Link 10: Chessie System, 1989-1994

This 464-mile link runs from Chicago, Illinois, to Pittsburgh, Pennsylvania. The traffic totaled 35 mgt in 1974. This link ranks about the same as the two following links.

Link 11: Chessie System, 1990-1995

This 318-mile link runs from Pittsburgh, Pennsylvania, to Washington, D. C. The traffic totaled 40 mgt in 1974.

Link 12: Chessie System/Southern, 1991-1996

This 716-mile link runs from Toledo to Cincinnati, Ohio, on the Chessie System, and then to Atlanta, Georgia, on the Southern, and hauled 30 mgt in 1974.

Link 13: Norfolk and Western, 1992-1997

This 255-mile link runs from Roanoke, Virginia, to Norfolk, Virginia. This link, with traffic of 40 mgt in 1974, connects to the other Norfolk and Western link, and hauls coal bound for export. This and the next link complete the electrification of major eastern routes.

Link 14: Illinois Central Gulf, 1993-1998

This 539-mile link runs from Chicago, Illinois, to Memphis, Tennessee. The traffic totaled 40 mgt in 1974.

These 14 links comprise the scenario of electrification that was selected for study. Although many of our assumptions and decisions, by necessity, were somewhat arbitrary, we believe that the rationale for adopting each link is plausible and results in a scenario that is useful for the study. Again, we emphasize that the scenario is not a forecast of where and when electrification will happen; rather, it is only a plausible presentation of how things could happen once electrification were deemed desirable and were begun.

V HOW CAN WE MODEL THE SYSTEM TO EXAMINE POTENTIAL IMPACTS?

What are the Assumptions?

The foregoing chapter presented a scenario for the electrification of 14 mainline links operated by 10 railroad companies. This chapter presents a framework for examining the consequences of this (or any alternative) scenario. Comparing, for the various stakeholders, the consequences of the status quo (continuing diesel operations on the network) with the consequences resulting from electrified operations is our first goal. Accordingly, our model includes parameters that relate to the interests of the various stakeholder groups. Because of the complexity of the problem, we formulated a model suitable for use with a computer.

The model requires many data about railroad operation, including the use of labor and capital equipment, practices related to financing capital purchases, and the like. Many assumptions are needed, both for sufficiently simplifying a complex system for study, and for assessing the effects of variation in such uncertain quantities as future demand for rail transportation and future interest rates. Thus, our model has been constructed so that the sensitivity of the outcome to alternative assumptions can be readily evaluated. This feature quickly reveals which assumptions are the most critical and, hence, which need more reliable inputs. Moreover, the changes in the consequences with changes in the assumptions may provide more interesting or valuable insights than the consequences of our scenario with its baseline assumptions.

A more important feature of our model is the internal consistency of the scenario consequences for stakeholders, for any given set of assumptions. Thus, decision makers who may use our work can feel confident that the conclusions about the significance of impacts of electrification for various stakeholders stem from a consistent basis.

Features of the Model

The central feature of the application of the model in this study is the treatment of the 14 links in the scenario as the mainlines of a single fictitious railroad company, a composite formed of the relevant parts of the 10 Class I railroad companies actually operating the links. We constructed an initial balance sheet for the composite for 1975 by apportioning the assets and liabilities of the Class I railroad companies to the composite company according to the proportion of mainline track of the Class I railroads included in the composite. Account statistics were taken from data published by the ICC (ICC, 1946-1975). ICC data also formed the basis for estimating unit costs of operation (see Appendix A for details of the data used in the model).

Primarily the model projects cash flow, income statements, and balance sheets, plus an array of operating parameters, annually from 1975 to 2025, well after electrification of the last link in the scenario. In response to an assumed freight demand schedule, operating costs are incurred and capital equipment is bought and sold. Revenues, freight rates, dividends, and requirements for new capital, for example, are generated by specified prescriptions built into the model. By running the model first with assumed use only of diesel locomotives, and then running it with electrification implemented according to the schedule in the scenario, the impact of electrification on each of the parameters simulated in the model can be determined and analyzed in detail.

Other notable features of our model include (see Appendix A for details):

- o All freight is classified into 3 commodity types (low-, medium-, and high-valuc) with separate rates.
- o Demand for freight transportation is specified separately for each of the 14 links.
- o Demand on each link is divided into two portions, only one of which is sensitive to freight rates and service.
- o Rolling stock is divided into diesel locomotives, electric locomotives, and freight cars.

- o Rolling stock in the fleet is in part leased and in part owned, has an assigned useful life, and is adjusted in numbers to meet demand.
- o Diesels that become surplus in the electrified scenario are sold or returned to lessors.

Data on the costs of electrification were taken from a study performed for the U.S. Department of Transportation's Federal Railroad Administration by A. D. Little, Inc. (Schwarm, 1976). Energy price forecasts were taken from a study performed by SRI International for the Electric Power Research Institute (SRI, 1977).

Financial Accounts

The gross flows of information in the model are shown in Figure 4.

FIGURE 4. MODEL INFORMATION FLOW

The input parameter driving the model is operations—the transportation of freight commodities according to the assumed demand schedule. From operations, expenses incurred and revenue derived are calculated, and the difference of those quantities comprises operating income. The contribution of depreciation to expenses is independent of operations. Then, following the general format and definitions of accounts used for the ICC reports from which our historical data are derived, interest is paid from operating income and the remainder contributes to profit. The other contribution to profit comes from sources related to railroading but not directly related to operations. Dividends are then paid from profits.

Information derived from the model thus far is used to construct the projected income statement. The accounts appearing in that statement are shown in Table 2. Railway operating expenses are calculated from nine separately projected expense categories, and rents are calculated in two categories.*

Table 2

INCOME STATEMENT

Railway Operating Revenues
Railway Operating Expenses
Diesel fuel
Electricity
Locomotive maintenance
Route maintenance
Track maintenance
Train crew
Rolling stock depreciation
Facilities depreciation
Other operating expenses
Taxes
Rents
Equipment
Facilities
Net railway operating income
Net other income
Interest
Profit

*Compared to the detailed ICC account format, our format is greatly simplified because we are interested only in the accounts depicted, which are a composite of the actual ICC accounts.

Similarly, we adopted a simplified balance sheet format:

BALANCE SHEET

<u>Assets</u>	<u>Liabilities</u>
Working capital	Equipment debt
Road and structures	Funded debt
Depreciable	Federal loan
Non-depreciable	Net worth
Rolling stock	Stock
	Retained earnings

Tangible assets are divided into road and structures, made up of depreciable and nondepreciable portions, and rolling stock, which is comprised of diesel locomotives, electric locomotives, and freight cars. Long-term debt is carried in three categories—debt with equipment as collateral, general obligation bonds (funded debt), and federal loans. The net worth is comprised of common stock and retained earnings. The net of all other accounts in the ICC format, mainly current assets and liabilities, is carried as working capital. Again, this simple format contains all the parameters that are of interest to stakeholders.

To see how the balance sheet is projected, other than the contribution of profit (after dividends) to retained earnings, we return to the information flows shown in Figure 4. We see that profit is also used to repay principal on the debt. Then, any remainder, together with the depreciation charges, comprises the internally generated funds from the period's operation. From those funds, working capital is adjusted as necessary to maintain the scale of operations, then any remainder is available for capital investment. Any shortage in internal funds for the capital investment requirements is relieved first by new equipment debt insofar as possible, and then with either additional other debt or equity as required. Other internal funds, not mentioned in the gross flow description (Figure 4), are derived from the proceeds of the sale of owned diesel locomotives that become surplus when electrified operation begins. Schedules built into the model repay debt, depreciate equipment, retire rolling stock, and pay dividends.

Transportation demand determines the acquisition of new equipment. The proportion of owned to leased equipment is fixed at historical values.

The sources and applications of funds are summarized by the following tabulations:

SOURCES OF FUNDS		APPLICATION OF FUNDS
Internal	External	Working capital
Profits	Equipment debt	Debt repayment
Depreciation	New capital	Dividends
Locomotive sales		Road and structure
		Rolling stock

The list for applications of funds comprises a hierarchy used in the model. Contrary to the conceptual gross flow description, for example, incrementing working capital has highest priority, followed by repayment of debt. Then, after dividends are paid, capital equipment improvements are financed using the remaining internal funds, any new capital needed for road and structures, and any equipment debt needed for new owned rolling stock.

Assumptions in the Model

The principal parameters for which explicit assumptions must be made are listed below:

- o Freight traffic growth
- o Net other income
- o Fuel and electricity prices
- o Inflation and interest rates
- o Investment tax credit
- o Alternative means of financing
- o Rate-setting regulatory practices

Because a reliable forecast of the values of these parameters to 2025 is unavailable, we have made plausible assumptions about future values, and then varied these numerical assumptions one by one to determine the sensitivity of our model's results to each assumption. Moreover, we believe that the information contained in that sensitivity analysis is more reliable, and is possibly of greater interest, than the absolute value of the numerical results overall.

Future Growth of Freight Demand

In light of stagnant demand during the last decades, zero growth might be expected. However, the growth anticipated in the transportation of coal alone suggests an increasing demand that will affect all of the high-use composite rail network we are considering. The increasing importance of the cost of energy in transportation may also affect the market share for railroads in nonbulk commodities, because the railroads' use of energy per unit of transportation is significantly lower than some competing modes. Considering those factors, our baseline assumption is that freight demand will increase at the rate of 1%/year except for the high-growth coal carrying line, the Burlington Northern link. On that link, traffic is assumed to increase at an average rate of 13%/year until the link is saturated in 1995 with three-track service. Using these assumptions, the baseline growth case is depicted in Figure 5 by a solid line. The dashed line shown reflects an alternative assumption of 2% growth (except for the Burlington Northern link) for testing the sensitivity of model results to demand for freight transportation. The effect of compound growth in demand even with seemingly small rates of growth is clearly evident.

Nonoperating Source of Income

"Net other income" is the term we use for the combination of two ICC accounts—"other income" and "miscellaneous deductions from income." Each of those accounts contains many subaccounts, which individually are not of interest in our model.

FIGURE 5. FREIGHT DEMAND GROWTH

At first glance it may appear that these accounts should not be included in our model because they are unrelated to the issue of electrification. However, this source of income is proportionally too large to ignore. Because we are interested in obtaining a good estimate of external financing that would be needed for electrification, we include net other income and correlate it with working capital. The linear correlation of these two accounts in the IUC data over a long time period justifies this assumption in light of our long-term perspective (see Appendix A).

Energy Prices

Our assumptions about energy prices are shown in Figure 6. Three features of that figure must be emphasized:

- o The vertical scale has dissimilar units for diesel fuel and for electricity

- o Purchase prices are shown, not energy costs for delivering the same unit of transportation
- o Prices are expressed in constant 1975 dollars; that is, inflation is removed.

Figure 6 shows that we have assumed that the price of diesel fuel in real terms (constant dollars) increases steadily until the year 2000; it continues to increase steadily thereafter, but at a lower rate until 2025, by which time it has nearly doubled in price relative to other commodities. The average price of electricity is assumed to decline slowly and steadily in real terms, although by only a few percent relative to other commodities. These assumptions are identical to the price forecasts made in a study SRI performed for the Electric Power Research Institute (SRI, 1977).

Briefly, the bases for these changes are the declining supplies of petroleum from fossil fuel resources that are finite in size and increasingly costly to recover (and for the United States to purchase from foreign sources), and technology improvements in the generation and transmission of electricity.

FIGURE 6. ENERGY PRICES

An alternative assumption studied is a constant real price for electricity (shown as a dotted line in Figure 6).

Inflation and Interest Rates

We specifically address the issue of inflation, and make assumptions about its course throughout our time period of interest. Whether the projected financial accounts are expressed in constant dollars or current dollars, the effect of inflation on depreciation and interest rates used in the calculation of expenses, and on the statement of assets and liabilities, must be properly assessed. For a projection of inflation over the long term we relied on the assumptions used by the trustees of the Social Security Administration (SSA, 1977). The baseline assumption is shown by the labeled line in Figure 7.

Alternative assumptions, also used by the SSA, consist of long-term inflation rates of either 3% or 5% after 1981; we used these assumptions to test the sensitivity of our results to the level of inflation.

Note: Alternative long-term assumptions are:
inflation at 3%, interest of 6%;
inflation at 5%, interest of 8%.

FIGURE 7. INFLATION AND INTEREST RATES

In all cases, the long-term interest rate is assumed to be 3% above the inflation rate, with an asymptotic approach to that rate from a 1975 level of 8%. The 3% long-term differential has considerable historical justification in spite of occasional anomalous relationships, such as in 1975 and shortly thereafter.

Briefly, our model handles inflation in the following manner:

- o First, all costs and revenues are calculated in current dollars. Thus, depreciation (based on historical cost) is appropriately understated; market rates for interest are used without adjustment; and the effects of delays in obtaining freight rate increases are assessed in a straightforward way.
- o The balance sheet is then incremented in current dollars. Thus, the financial accounts accumulate mixed dollars, as in reality.
- o Finally, our results are presented graphically in constant, 1975 dollars (with one exception), by deflating each projected statement with the cumulative inflation factor for that year. This is a pragmatic approach as well as a conceptually consistent one--inflation is so great over the period we examine that most of the graphs would be dominated by the exponential rise in values expressed in current dollars, completely masking other effects sought for analysis.

Investment Tax Credit

Because the investment tax credit has been very important to railroads, and because the laws regulating those credits have changed frequently in recent times, it is important to recognize that maintenance of current credits represents an assumption and that alternative assumptions should be tested. When our model was built and run, the law allowed tax credits for qualifying investments according to the solid line in Figure 8, 10% declining to 7% after 1980. Alternatively, to discover the effects of a change of tax credits explicitly, we examined the consequences of a doubling of the credit and of the elimination of the credit after 1980.

FIGURE 8. INVESTMENT TAX CREDIT

Alternative Means of Financing

A principal consideration of our study is financing railroad capital improvements, particularly the capital intensive step of electrification. Consequently, we have examined several alternative means of financing electrification:

- o Sale of common stock (baseline assumption)
- o Long-term debt
- o Federal loans.

In each case, we assume that equipment (i.e., rolling stock) can be financed with equipment debt. In contrast with equipment debt, we assume the long-term debt option is unsecured by collateral, but perhaps guaranteed by the federal government if such a guarantee is necessary to make it feasible. Although the long-term debt and equipment debt are assumed to obligate interest payments at

the interest rate for the year the debt is incurred (basically 3% above the inflation rate), we assume the corresponding interest rate on a federal loan would be 1.5% above the inflation rate.

Freight Rates

Because of inflation and the relative rise in the price of diesel fuel, railroads must repeatedly apply to the ICC for rate increases. Although we can discern no formal ICC policy that guides the approval of such freight rate requests, examination of historical data relating operating revenues to operating costs reveals a direct proportionality. We assume that this historical relationship continues, and we refer to it as "cost-based" rate setting. Because other regulated entities (e.g., electric utilities and telephone companies) have rates based on an equitable return on investment, we also consider the alternative of "investment-based" rate setting.

Delays inherent in the regulatory process affect revenues, especially in an inflationary environment. Consequently, we examined two assumptions:

- o 5-month delay (baseline assumption)
- o 7-month delay

The first assumption corresponds to the briefest delays recorded in recent experience. The second assumption allows us to explore the sensitivity of results to regulatory delay.

Other Assumptions

Other necessary assumptions (e.g., unit costs for transportation) are cataloged in Appendix A. Still other assumptions are implicit; for example, the assumption that unit labor costs remain constant in real terms in turn implies that real wage gains are not made unless corresponding productivity improvements occur. None of these assumptions is expected to affect (or be affected by) electrification significantly.

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VI WHAT ARE THE POTENTIAL ECONOMIC CONSEQUENCES OF ELECTRIFICATION?

In the preceding chapter we described the model we developed to use as a framework for examining the consequences of electrifying railroads. (The same model could be used to examine many other alternative futures in railway transportation.) This chapter presents the results of using the model to examine the consequences of mainline electrification according to the scenario developed in Chapter IV. We first detail the consequences of electrification for the composite rail network, which consists of 14 mainline links. We then discuss the consequences for a single operating company, the Santa Fe (Atchison, Topeka, and Santa Fe), which operates two of the links in the composite network. By contrasting the results for a single company with the results for the composite company, we gain insight into the strengths and limitations in each application of the model.

Next, we present a critical examination of the assumptions used in the foregoing analyses. By studying the impact on the outcome of varying one assumption at a time, the importance of each assumption becomes apparent. Moreover, because several of the assumptions relate to public policy alternatives, the effect of various public policies on railroads—both with and without electrification—can readily be explored.

Electrification of the Composite Company--A Base Case

In our initial analysis of the future of our composite railroad company, both with and without electrification, we first summarize the baseline assumptions used in the model.

- o Freight transportation demand grows at a basic rate of 1%/year (13%/year average on the Burlington Northern coal-hauling link).

- o Net other (nonoperating) income is included.
- o During the 50 year period, the constant dollar price of diesel fuel nearly doubles, whereas the price of electricity declines slightly.
- o Inflation approaches 4% and the long-term interest rate approaches 7% during the period.
- o The investment tax credit is 10% through 1980 and 7% thereafter.
- o Electrification of mainline track is financed through the sale of common stock.
- o Freight rates are related to historical costs, and new rates are implemented with a delay of 5 months.

Using these assumptions, the operations of the composite company for the years 1975 through 2025 are displayed graphically throughout this section for two cases—diesel and electrified mainline operations. (Of course, some diesel locomotives must always be used for yard and siding operations, even after all mainlines have been electrified in the latter case.) The figures throughout this chapter display only the key model parameters that are most helpful in understanding the consequences of electrification. The parameters that are measured in dollars are, with one prominently noted exception (equity, in Figure 36), expressed in constant 1975 dollars.

Rolling Stock Requirements

The increase in demand assumed for freight transportation in turn implies a steady increase in the rolling stock inventory required to accommodate it. Figure 9 shows an example of the traffic increase for one link—the Union Pacific. Traffic is slightly higher for the electric case because, as we note later, demand increases in response to the lower freight rates (from; lower operating expenses) in that case. In contrast with other links in the composite, Figure 10 shows the rapid increase in traffic assumed on the Burlington Northern link. Traffic saturates this link in both cases, but the maximum amount of traffic is higher in the electric case because of the greater speed of electrified trains up the "ruling grade" (that grade that results in slowest speed on the link).

The total traffic for all links of the composite company is shown in Figure 11. Demand nearly doubles during the 50-year period. For the electric case, the division of traffic into diesel- and electric-powered trains during the transition period is shown in Figure 12.

Figure 13 illustrates the impact of the transition and of traffic growth and shows orders for new locomotives that are required. In the electric case, orders for new diesels vanish during the transition period, to reappear afterward as replacements are ordered for yard locomotives. In fact, many diesels become surplus during the transition and are sold or returned to lessors. Orders for new electric locomotives are initially strong during the transition. However, because fewer electrics than diesels are needed for the same service (see Chapter 2), orders settle to a level that is much lower than the order level for diesels in the diesel case, in spite of greater traffic. The accumulated inventories of locomotives are shown in Figure 14.

Figure 15 illustrates the implication that the transition to electric operation on our composite railroad has for the market for locomotives in 1990, for example. The diesel market shown represents the expected number of orders from the domestic market, excluding our composite network. The diesels our composite company sells or returns to the lessors could satisfy approximately half of the domestic market for that year. For comparison the electric locomotives delivered that year are also shown.

Similarly, Figure 16 shows the requirements for new freight cars, and Figure 17 shows the resulting freight car inventories. The portion of freight cars leased is indicated; although not shown, a similar proportion of the locomotives is assumed to be under lease.

Demand increases moderately on most links ...

FIGURE 9. TOTAL LINK TRAFFIC – UNION PACIFIC LINK

... but demand quickly saturates this coal carrying link

FIGURE 10. TOTAL LINK TRAFFIC – BURLINGTON NORTHERN LINK

Total traffic for all links ...

FIGURE 11. TOTAL COMPOSITE TRAFFIC

... becomes increasingly electrified ...

FIGURE 12. TRAFFIC BY LOCOMOTIVE TYPE—ELECTRIC CASE

... Affecting requirements for locomotives ...

FIGURE 13. NEW LOCOMOTIVE REQUIREMENTS

... Causing the locomotive inventory to change dramatically

FIGURE 14. LOCOMOTIVE FLEET

In fact, many diesel locomotives become surplus

FIGURE 15. LOCOMOTIVE MARKET

More freight cars are needed ...

FIGURE 16. NEW FREIGHT CARS REQUIRED

... causing growth in freight car inventory

FIGURE 17. FREIGHT CAR FLEET

Operating Costs and Energy Requirements

As Figure 18 indicates, operating costs overall are slightly reduced in the electric case. A detailed comparison is shown in Figures 19 and 20; most costs would not differ for the two cases.

Operating costs are reduced moderately ...

FIGURE 18. RAILWAY OPERATING EXPENSES

... because without electrification fuel costs would increase

FIGURE 19. OPERATING COST COMPONENTS - DIESEL

Depreciation increases slightly for the electric case, but locomotive maintenance costs and energy costs decline, particularly the latter costs. More detailed comparisons are shown in Figures 21 and 22. The growth of expenses for electricity does not match the decline in diesel fuel expenses—a result of our assumptions about energy prices. The actual quantities of energy forms purchased are compared in Figure 23. (Note that the scales for diesel fuel and electricity are different.) By 2025, about 1.2 billion gal of diesel fuel would be replaced by about 15 billion kWh of electric power if our composite company were electrified.

Input data relating the energy efficiency of diesel and electric locomotive operation are reflected in the Figure 24 comparison, which is based on the use of petroleum as the primary energy resource. Figure 25 makes the same sort of comparison, but it is based on the use of coal as the primary energy resource. When diesel fuel must be synthesized from coal, approximately twice as much of the coal resource is required than for generating electricity by burning coal.

*Energy and locomotive maintenance
costs decline, depreciation increases*

FIGURE 20. OPERATING COST COMPONENTS — ELECTRIC

Electrification requires less locomotive maintenance ...

FIGURE 21. LOCOMOTIVE MAINTENANCE COST

... and reduces energy costs ...

FIGURE 22. ENERGY COSTS

... changing demands placed on energy suppliers

FIGURE 23. DIESEL FUEL AND ELECTRICITY USE

Energy efficiency is improved moderately ...

FIGURE 24. PETROLEUM-BASED ENERGY EFFICIENCY

... and improved greatly for synthetic diesel fuel

FIGURE 25. COAL-BASED ENERGY EFFICIENCY

Operating revenues based on operating expenses ...

FIGURE 26. RAILWAY OPERATING REVENUES AND EXPENSES

... determine the average freight rates

FIGURE 27. AVERAGE FREIGHT RATES

Income rises with electrification ...

FIGURE 28. NET INCOMES

... but so do interest payments ...

FIGURE 29. INTEREST

... resulting in lower earnings ...

FIGURE 30. PROFIT

... and erosion of the equity added for electrification

FIGURE 31. NET WORTH

Financial Consequences

The unit costs and traffic levels shown above combine to yield the composite railroad operating expenses shown in Figure 26. Then the revenues from operations, also shown, are projected so that the historical ratio of expenses to revenues is maintained. The lower unit costs for the electric case are more than offset by the higher level of traffic, resulting both in increased expenses and revenues. From these parameters the freight rates are determined, as shown in Figure 27. Rates are slightly lower for the electric case when our baseline assumptions are used.

Figure 28 sets forth net operating income (revenues less expenses), along with net other (nonoperating) income. The latter is slightly higher for the electric case because it is assumed to be proportional to working capital which, in turn, keeps pace with revenues. Thus, net other income is indirectly related to the level of operations.

Although income is higher for the electric case, the burden of interest (mainly on equipment debt, see below) that results indirectly from the capital intensive investment in electrification facilities makes a much higher demand on income, as seen in Figure 29. For both cases, interest climbs rapidly as long as the coal-hauling Burlington Northern link has an average 13% growth rate in traffic. After this link becomes saturated, at different times in each case (because of differing maximum amounts of traffic), interest payments decline just as rapidly as the debt is reduced. But the peak reached in the electric case is about 50% higher than in the diesel case.

Consequently, as Figure 30 indicates, earnings (income less interest) are significantly lower in the electric case for an extended period. Earnings finally recover after 2015 to the level projected for the diesel case. Coupled with lower earnings is an increase in the equity of the composite company brought about by the sale of common stock to finance the electrification facilities. The combined picture for net worth of the composite company is shown in Figure 31.

We see that although equity increases initially as stock is sold, it is eroded by the lower earnings in the electric case. Consequently, by the end of the study period the net worth of the composite railroad company is about the same in both cases.

Figure 32 illustrates an alternative view of these consequences. The rate of return on equity (ROE) is defined as earnings (or profit) divided by net worth. Because we assume continuation of the historical relation of revenues to expenses, of dividend policy, and of other parameters in the diesel case, the ROE is essentially constant during the scenario period and provides a benchmark for comparison. For the electric case the ROE suffers considerably for an extended period, until the debt is significantly reduced. Figure 32 also shows the rate of return on investment (ROI), commonly used in the railroad industry, and defined as net operating income divided by operating assets (in our case, rolling stock plus road and structures accounts). This index thus ignores net other income and interest expense as well as indebtedness, focusing instead on the operating return from operating assets. Nonetheless, the picture presented is similar to the equity measure. ROI declines significantly for an extended period because the slightly improved net operating income in the electric case is more than offset by the increased investment in electrification of road and structures, and to a much lesser extent, in rolling stock, as is shown later.

Thus it appears that electrification is not an attractive prospect for the operators and owners of a railroad like our composite company under base case assumptions. The central reason for the reduced profitability is that revenues, and ultimately freight rates, are based on operating expenses. These expenses do not reflect the cost of investment—whether financed by debt or equity, or a combination of the two. Alternative assumptions about this apparent deficiency are addressed below.

Our base case illustrates the impact of profitability and depreciation charges on the funds internally available for investment. Figure 33 shows a significant decline in those internal funds in the electric case, and for

Consequently, profitability suffers when rates are tied to operating costs ...

FIGURE 32. RATE OF RETURN

... and internal funds for investment are diminished

FIGURE 33. INVESTMENT FUNDS

comparison also shows the external funds required to complete electrification of the road and structures. We assume that equipment bonds are always available to finance owned rolling stock, whether it is electric or diesel. The external funds required (see Figure 33) are raised by sale of common stock in our base case.

The new investment in operating assets for both cases is shown in Figure 34. The incremental investment in rolling stock needed for electrification is modest, rising only during the additional time required for the electrified coal-hauling Burlington Northern link to become saturated. The investment in road and structures—for electrification—is often characterized in the literature as unprecedented in scope. It certainly is substantial, as Figure 35 indicates. However, when we contrast this investment with that required for rolling stock, as in Figure 34, we see that the persistent demand for investment funds for rolling stock averages more than double the investment in electrification facilities required during the construction period and that the rolling stock investment demand continues unabated. Although the investment in facilities is undeniably significant, it certainly does not dwarf other investment.

The external funds required to complete the electrification of facilities, shown in Figure 33, are obtained by sale of common stock in our base case. The resulting increase in the common stock account on the balance sheet of our composite company is indicated in Figure 36, shown in current dollars and only through the year 2000 in contrast with all other figures. The common stock account more than doubles during the period of facilities construction, but because retained earnings grow more slowly in the electric case, the increment to net worth shown is smaller than for common stock. The current dollar net worth curves in this figure may be compared with the constant dollar ones in Figure 31, but note that the time scales are different.

*Additional investment funds are
needed for electrification ...*

FIGURE 34. INVESTMENTS REQUIRED

... greatly increasing investment in road and structures

FIGURE 35. TOTAL ROAD AND STRUCTURE INVESTMENT

**Shareholders provide the external funds required
to complete electrification ...**

FIGURE 36. SHAREHOLDERS' EQUITY

Because funds available internally (see Figure 33) are applied to the investment in electrification of facilities and because we assume that equipment debt is always available to finance rolling stock investment, equipment debt increases considerably in the electric case (see Figure 37). Again, the longer climb in the electric case is attributed to the later saturation of the coal-hauling Burlington Northern link. However, because the equity increase in the electric case partly offsets the debt increase, Figure 38 shows a modest increase in the peak debt/equity ratio. Although the debt/equity ratio increase persists, the results suggest that normal financing of rolling stock could be expected in the electric case.

... but the added burden of debt is large ...

FIGURE 37. LONG-TERM DEBT

... and the debt/equity ratio increases moderately

FIGURE 38. DEBT/EQUITY

Base Case Summary

With electrification of facilities, our model has shown that costs are reduced largely because of lower energy costs and, to a lesser extent, because of decreased locomotive maintenance. However, inasmuch as we assume that historic ratios of railway operating revenues to expenses are maintained, profitability comparable to that of the diesel case is not achieved. Whereas it appears that financing of the rolling stock would be feasible, the unattractive profitability projected suggests that financing the electrification of facilities through sale of common stock would not be feasible. Indeed, it would appear unattractive to current owners of common shares.

Electrification of the composite railroad would yield a slight decrease in energy use per gross ton-mile of freight transportation in the electric case. However, should diesel fuel have to be derived from coal, energy use in the electric case would be about half that for diesel.

These conclusions all follow from our base case assumptions and other data used in our railroad model. To gain further insight into the consequences of electrification and, to learn how conclusions drawn for the larger composite may differ from conclusions drawn by individual railroad companies, we selected two of the 14 links for chosen scrutiny. The links selected are the two operated by the Santa Fe.

Electrification of the Two Santa Fe Links--A Comparison Case

The two links of the Santa Fe are now considered as an operation separate from the rest of the Santa Fe, and are derived from the ICC accounts (ICC, 1946-1975) for the Santa Fe in the same way as the accounts for the 14 link scenario were derived from accounts for Class I railroads.

Because we are dealing with only two links, the transition to electrified operation is more abrupt. Figure 39 shows the change in operations as two discrete transitions occurring at the same time as in the complete scenario. Although only mainline operations are shown for the Santa Fe on these two links (a fraction of Santa Fe's total track mileage), it is clear that the transition will be more abrupt for any railroad smaller than our 14-link composite company.

Figure 40 shows that, in contrast to the effect seen for the composite company, operating expenses (and hence revenues) are reduced for the Santa Fe links because the modest increase in demand does not fully offset the lower unit operating costs. Consequently, freight rates fall further than for the composite (see Figure 41), and net income falls instead of rising (see Figure 42). The 2 years of sharply increased net operating income result from investment tax credits taken in those years.

Operations change abruptly from diesel to electric

FIGURE 39. TRAFFIC BY LOCOMOTIVE TYPE

Operating costs and revenues are reduced for the Santa Fe

FIGURE 40. RAILWAY OPERATING REVENUES AND EXPENSES

Consequently, rates fall further ...

FIGURE 41. AVERAGE FREIGHT RATES

... leading to a reduced net income

FIGURE 42. NET INCOMES

The impact of increased investment in road and structures, shown in Figure 43, is somewhat greater for the Santa Fe, and results in increased depreciation charges. Thus, Figure 44 shows that funds available internally increase, in contrast with the composite company; the need for external funds is also concentrated during the two electrification periods.

Because of the greater flow of internal funds, debt (and interest payments) can be more rapidly reduced for the Santa Fe links, and a more rapid rebound in profit follows. These effects are shown in Figures 45 and 46. Again, the peaks in profit result from the investment tax credits.

Road and structure investment has more impact ...

FIGURE 43. TOTAL ROAD AND STRUCTURE INVESTMENT

... providing increased depreciation and internal funds ...

FIGURE 44. INVESTMENT FUNDS

... allowing rapid repayment of debt
and lower interest cost ...

FIGURE 45. LONG-TERM DEBT

... and a more rapid recovery of profits ...

FIGURE 46. PROFIT

Because debt is lowered more rapidly, the debt/equity ratio (see Figure 47) is greatly reduced, in contrast with the increase found for the composite company. But also contributing to the reduced debt/equity ratio is a far greater increase in equity (see Figure 48) than for the composite company. Consequently, because both equity and investment increase so greatly, the rates of return on each suffer more than for the composite company in spite of better profit recovery on the Santa Fe, as can be seen in Figure 49.

In summary, several differences from the composite may occur for operations that are part of a single railroad company. In general, transitions can be expected to be more abrupt and to have more effect on any company smaller than the composite company. Moreover, the proportional increases in investment and in equity brought about by electrification have a larger bearing on rates of return than for the larger composite company.

... as well as a lower debt/equity ratio

FIGURE 47. DEBT/EQUITY

A marked increase in net worth ...

FIGURE 48. NET WORTH

... reduces the rate of return on equity

FIGURE 49. RATE OF RETURN

Even earlier improvement in profits would not counter the larger increase in equity, and the ROE would suffer more and longer than for the composite. Put another way, if the marginal ROE or ROI is lower than the return on the original operation, the impact is greater the larger the relative increase in equity or investment.

Again, as for the composite case, we stress that the picture presented for the Santa Fe links follows from the assumptions made. In particular, the assumption that freight rates are determined from the historical relationship that has existed between operating revenues and operating expenses is critical. Other assumptions for the Santa Fe, as well as for other railroad companies with links in the composite company, deserve further study. We present this study of the Santa Fe links primarily to demonstrate some of the limitations of the composite company approach and to highlight problems that may be faced by decision makers concerned with electrification of an individual company. To investigate the effects of alternative assumptions on our conclusions, we return to the study of the 14-link composite company.

Electrification of the Composite Company-Alternative Cases

The effect on the composite company of changing some of the assumptions we have made, for the purpose of obtaining explicit, quantified information relating to the interests of the various stakeholder groups, is presented below. We emphasize alternative assumptions in three categories:

- o Regulatory practices
- o Financing alternatives
- o Indirect federal policy impacts.

For each alternative assumption in the study, and for certain combinations of alternatives, we evaluated all of the parameters discussed for the base case in the

first section in Chapter VI. (We also studied other parameters in the model for all cases to gain a comprehensive understanding of the results, but we have included only the most important and illustrative ones in this report.) Fortunately, a new discussion of every parameter is not necessary to illustrate the significance of the altered assumption. Thus, only a few parameters have been selected in each case for discussion in this section of the report.

Regulatory Practices

Regulatory practices—specifically the setting of freight rates—are of interest for several stakeholder groups. Thus, besides the railroads, shippers and, ultimately, consumers are most directly affected. The ICC must approve freight rates charged by the railroads because that agency is obligated to consider the public's well-being as well as that of the railroads in acting on rate issues.

Chapter V addressed the alternatives of assuming rates based on operating costs or on a principle of equitable ROI. In this section, we further consider basing rates for electrified operation on the operating costs that would have been incurred by diesel operation instead of the new electrified operation as in our base case. Because only one rate will apply between two points for a given commodity class, and because operating costs are lower for electrified lines, a diesel operations rate that is charged both by an electrified line and by a competing diesel line would yield a higher operating income to the electrified line. Hence, this sensitivity test addresses the circumstances in which both types of service continue in competition between points served by the composite company. At our workshop, most railroad decision makers believed that this condition would exist—at least for a few years after electrification.

With the inclusion of regulatory delay, together with the rate-setting mechanisms under consideration, we have three sets of assumptions alternative to the base case:

- o Freight rates are set to yield a fixed ROI instead of a fixed mark-up on operating costs.
- o Freight rates of electrified links are set to reflect a fixed mark-up on the operating costs of diesel lines instead of electrified lines.
- o Regulatory delay in rate approval increases from 5 to 7 months.

The following sections look at each set of assumptions in turn, comparing the results with the base case.

Investment Based Rate Setting. In this alternative, freight rates are set so that the rate of ROI (investment includes all assets, less working capital) is targeted at the same value as that for 1975. Because of inflation, rate increases must be sought periodically as in the base case; they are implemented after a regulatory delay. The model result is shown in Figure 50: ROI remains essentially constant instead of declining severely as it does for cost-based rate setting. Figure 50 also shows that the ROE remains nearly constant instead of declining for a significant period. Hence, both measures of performance important to railroad investors can be maintained on the principle embodied in this alternative. The fixed percentage of ROI is arbitrary, but using the 1975 base allows a direct comparison with our base case. (It should not be inferred from this example that we judged the 1975 rates of return to be reasonable and proper.)

The rates of return are maintained by greatly increased net operating income (see Figure 51). Operating income grows with new investment until electrification is completed; it then declines as these assets are depreciated. The freight rates required to provide the improved operating income are shown in Figure 52. That figure shows that relatively small increases in freight rates, which are ultimately borne by consumers, are needed for about a 25-year period.

Profitability is restored ...

FIGURE 50. RATE OF RETURN UNDER TWO ALTERNATIVE REGULATORY PRACTICES

... as operating income rises ...

FIGURE 51. NET INCOMES UNDER TWO ALTERNATIVE REGULATORY PRACTICES

... because of slightly higher freight rates

FIGURE 52. AVERAGE FREIGHT RATES UNDER TWO ALTERNATIVE REGULATORY PRACTICES

So, the need for external funds is reduced

FIGURE 53. INVESTMENT FUNDS UNDER TWO ALTERNATIVE REGULATORY PRACTICES

The improved operating income greatly increases the availability of internal funds for investment. Figure 53 shows that internal funds availability does not decline as it does in the base case; in fact, it remains higher throughout the period of coverage. The funds required from external sources are somewhat less than for the base case from 1989 through 1991, and from 1991 through the end of the electrification program in 1997 the requirements are far less. The issuance of common stock to meet those requirements declines from \$2.45 billion to \$1.4 billion (current dollars), for the whole electrification period. Most of the \$1 billion decline in new demand on the capital markets comes in the last decade of this century.

Hence, it appears that a relatively small, temporary increase in freight rates can significantly affect the maintenance of the ROI, as well as the need for external funds to finance electrification.

Rate Setting Based on Costs of Diesel Operation. In this alternative, freight rates for electrified service are based on the cost of providing equivalent diesel service. The improvement in profitability is dramatic (see Figure 54). By the end of the period, the ROI approximately doubles to more than 16% and the ROE increases from about 13 to 18%. The rise is propelled mainly by greatly increased operating income (see Figure 55). In contrast with the investment-based rate-setting alternative above, operating income diverges from the base case throughout the period. Consequently, the funds internally available for investment increase even more in this alternative, as seen in Figure 56. However, because the increase comes later, the need for external funds during electrification is about the same as for the investment-based rate-setting alternative (i.e., about one billion current dollars less than for the base case). Hence, the main effect of increased internal funds is to reduce equipment debt after electrification is completed.

Profitability recovers and then rises steadily ...

FIGURE 54. RATE OF RETURN UNDER TWO ALTERNATIVE REGULATORY PRACTICES

... as operating income expands ...

FIGURE 55. NET INCOMES UNDER TWO ALTERNATIVE REGULATORY PRACTICES

... and internal funds balloon

FIGURE 56. INVESTMENT FUNDS UNDER TWO ALTERNATIVE REGULATORY PRACTICES

Freight rates are moderately higher

FIGURE 57. AVERAGE FREIGHT RATES UNDER TWO ALTERNATIVE REGULATORY PRACTICES

Figure 57 shows that the corresponding freight rates, which diverge throughout the period, are moderately higher than for the base case. This result is in contrast with the investment-based rate-setting alternative (Figure 57), in which the increase is smaller and temporary. Consequently, the overall impact on consumers in the present alternative is larger and more persistent.

This alternative bears some relation to the usual discounted-cash-flow (DCF) calculation performed to compare the profitability of diesel and electrified operations on specific routes, and so to find the ROI in electrified facilities. Such calculations usually show the conversion to electrified operation to be quite profitable; at the same time, however, they assume continuance of the present freight rate schedule in a constant dollar calculation. That assumption appears to us to be tantamount to assuming rates based on the cost of diesel operation. Consequently, whether the calculated profitability is realized would appear to depend on the continuance of a rate schedule based on the costs of diesel operation. That assumption, in turn, must rely (1) on the continued operation of diesels on competing routes and, correspondingly, on the maintenance of freight rates at a level adequate to allow historical profits on the competing routes or (2) on a significant departure from the historical relationship between actual operating costs and allowed revenues. It is important to recognize those underlying assumptions in analyzing the DCF calculations of the ROI of electrification, and in comparing those results with the results of this report.

Increased Regulatory Delay. In this alternative assumption, diesel operation is used to compare results of a 7-month regulatory delay with the results for the 5-month delay of the base case. The direct result on freight rates is shown in Figure 58. Although the reduction shown in freight rates is slight, it nonetheless has a moderate impact on profit (see Figure 59) and on the funds available internally for investment, seen in Figure 60. Similarly, the rates of return shown in Figure 61 are significantly reduced.

The reduction in ROE does not persist because the reduced profit significantly reduces the accumulated equity over the long term; that is, shareholders suffer both reduced dividends on profits and reduced equity. Thus, the convergence of ROE (the ratio of reduced profit to reduced equity) with the base case ratio merely gives the appearance of a temporary setback.

It is clear that even modestly increasing the delay in granting approvals for rate increases, in an inflationary environment, can significantly decrease profitability and affect other financial parameters over both short and long terms. (The specific effects of inflation are discussed below.) Consequently, ICC policies in regard to expeditious handling of requests for approval of rate increases appear to be important, and thus deserve consideration along with the broader issues of basis for rates, and reasonable and proper rate of return.

Financing Alternatives

Financing electrification is a central issue that affects various stakeholder groups. Most directly affected are the railroad companies and the institutions that provide funds for capital expansion—holders of equity and debt on railroads and, in some alternatives, members of the taxpaying public. The ultimate consumers of freight service are also affected; they have a stake in the feasibility of the financial arrangements because their freight rates may be changed (at least under some alternative rate-basis assumptions).

Chapter V described the alternatives of assuming that capital is raised through sale of common stock (base case), offering of long-term debt, and federal loans. This section also considers the alternative of the federal government paying for, owning, and maintaining the improvements in road and structures. In this case, competing carriers would have access to the electrified road and would pay some equitable portion of the costs for facilities unrelated to the electrification. This case is thus akin to federal support of construction and maintenance of interstate waterways and highways.

Freight rates lag slightly ...

FIGURE 58. AVERAGE FREIGHT RATES UNDER TWO ALTERNATIVE REGULATORY DELAYS

... causing significantly reduced profit ...

FIGURE 59. PROFIT UNDER TWO ALTERNATIVE REGULATORY DELAYS

... and diminished internal funds available

FIGURE 60. INTERNALLY AVAILABLE INVESTMENT FUNDS UNDER TWO ALTERNATIVE REGULATORY DELAYS

Profitability is significantly reduced

FIGURE 61. RATE OF RETURN UNDER TWO ALTERNATIVE REGULATORY DELAYS

The financing mechanisms considered alternative to the base case are:

- o Long-term debt
- o Federal loans
- o Government ownership of road and structure electrification facilities.

Each of those alternatives is considered below in turn and each is compared with the base case and selected other alternatives. Of course, combining some of those financing options (including the base case) would be feasible, but by examining one at a time we can more easily discern the effects of each.

Long-Term Debt. In this alternative assumption, the road and structure improvements for electrification are financed by some form of new funded debt. Because the equity is not diluted by new stock sales, the ROE is considerably improved, as shown in Figure 62. However, the sharp drop during the period of electrification is not eliminated, and the ROI is unaffected. The improvement in ROE comes about despite lower profits, as seen in Figure 63, because the growth in equity that is avoided is a larger factor. Profits are lower because of the added debt burden (see Figure 64). The new funded debt becomes a significant fraction of the total debt and, because of higher interest payments, indirectly leads to a slightly increased equipment debt after electrification is completed.

It is interesting to compare the situation shown in Figure 64, which assumes freight rates are based on operating expenses (base case assumption on freight rates), with the one shown in Figure 65, which assumes that freight rates reflect a fixed ROI. That is, two alternative assumptions are made at one time--debt financing and investment-based rates--and compared with the base case. The requirement for new funded debt is considerably reduced, and equipment debt is somewhat reduced. The improved profit with investment-based rates is responsible for both those debt reductions, which come in spite of the higher interest payments.

Similar comparisons of debt and stock financing with both cost and investment based rates can be made of the debt/equity ratios. Figure 66 illustrates the surge in debt/equity ratio that accompanies debt financing. Because the ratio goes well above unity, financing electrification on the composite railroad solely with debt does not appear to be feasible so long as freight rates are based on historical ratios of operating revenues to expenses. On the other hand, Figure 67 shows that the debt/equity ratio is restrained to near unity at the peak when freight rates are based on the fixed ROI previously assumed. Clearly, the feasibility of debt financing, in whole or part, depends strongly on the basis for setting of freight rates. Thus, debt financing alone does not present an attractive alternative, and the attractiveness of electrification depends much more strongly on assumptions about the basis for setting of freight rates.

Federal Loans. In this alternative, we assume that the electrification of road and structures is financed with federal loans. Other than the source for funds, this alternative assumption is principally distinguished from the long-term debt alternative in that the federal loans are repaid starting after electrification is completed. In addition, the interest rate for federal loans is assumed to be only 1.5% above the prevailing inflation rate, instead of 3% above for other debt.

Figure 68 when compared with Figure 64, shows that federal financing mainly transfers the debt burden to the equipment. The enhancement in equipment debt happens because internally available funds are used preferentially to repay the federal loans. By 2010 the federal loans are repaid, but repayment of equipment debt is set back about 6 years in comparison with the long-term debt alternative. Hence, overall debt or debt/equity ratios are little different in the two alternatives.

Again, if the investment-based freight rates alternative is combined with our financing alternative (see Figure 69), federal loans are reduced significantly and repaid by 2003, 7 years sooner than the case with cost-based freight rates. Furthermore, equipment debt is hardly affected in comparison with the base case.

Return on equity is improved ...

FIGURE 62. RATE OF RETURN UNDER TWO FINANCING ALTERNATIVES

... in spite of lower profits ...

FIGURE 63. PROFIT UNDER TWO FINANCING ALTERNATIVES

... resulting from added debt burden

FIGURE 64. LONG-TERM DEBT UNDER TWO FINANCING ALTERNATIVES

But, debt is reduced if freight rates reflect fixed return on investment

FIGURE 65. LONG-TERM DEBT UNDER TWO ALTERNATIVES OF FINANCING AND REGULATORY PRACTICE

The debt/equity ratio becomes excessive ...

FIGURE 66. DEBT/EQUITY UNDER TWO FINANCING ALTERNATIVES

*... unless freight rates reflect fixed
return on investment*

FIGURE 67. DEBT/EQUITY UNDER TWO ALTERNATIVES OF FINANCING AND REGULATORY PRACTICE

Equipment debt is enlarged ...

FIGURE 68. LONG-TERM DEBT UNDER TWO FINANCING ALTERNATIVES

*... unless freight rates reflect fixed return
on investment*

FIGURE 69. LONG-TERM DEBT UNDER TWO ALTERNATIVES OF FINANCING AND REGULATORY PRACTICE

Profitability is maintained ...

FIGURE 70. RATE OF RETURN UNDER TWO FINANCING ALTERNATIVES

*... as profit is unhampered by higher
interest payments ...*

FIGURE 71. PROFIT UNDER TWO FINANCING ALTERNATIVES

... because debt is lower

FIGURE 72. LONG-TERM DEBT UNDER TWO FINANCING ALTERNATIVES

Hence, the attractiveness of financing with federal loans depends strongly on the basis for setting freight rates, just as was the case for the assumption of using long-term debt, and for the same reasons.

Government Ownership. In this alternative, it is assumed that the electrification of road and structures is wholly paid for, and maintained by, the federal government. In this event, profitability is maintained in terms of ROE and ROI (see Figure 70) because the impact of higher interest payments on profits is avoided (see Figure 71). Secondly, avoiding the dilution of equity also helps maintain the ROE. Figure 72 illustrates the avoidance of debt and correspondingly higher interest payments; the funds internally available for investment continue to be applied to equipment needs instead of being diverted to help pay for electrification.

Clearly, the financial burden on railroads is lessened by the government support and maintenance assumed, which is analogous to federal support for highways and waterways. On the other hand, unlike highways and waterways used in interstate commerce, railways are privately owned. For electrification to take place in this instance, equitable joint-use agreements would have to be worked out that would protect the interests of the host railroad, other railroad companies using the facilities, users of the transportation services, and members of the taxpaying public. The model used in this study assumes that such arrangements are made, and that unit costs and freight rates are not perturbed as a result.

Indirect Federal Policy Impacts

In this section impacts on the outcome of railway electrification that can be attributed to federal policies not specifically directed toward the railroads are considered, in particular:

- o Investment tax credits
- o Inflation and interest rates.

Federal policies, laws, regulations, and other initiatives are intended to regulate the general conduct of business in the economy. However, different segments of the economy may be affected unequally; if that result is not desired, special rules may be made for certain segments (e.g., rules concerning investment tax credits that apply to railroads). Here, however, we consider alternative futures for tax credits, inflation, and interest rates as these measures affect railroads, whether or not the measures results from special rules.

Investment Tax Credits. The direct effect on tax payments of the alternative tax credits allowed for investment is shown in Figure 73 for the electrified case. A doubled credit translates into approximately 1 percentage point increase in profitability, and a removal of the credit decreases profitability nearly 1 percentage point (see Figure 74). The improvement in profitability with

increasing credits diminishes after the year 2000—mainly because of the increase in equity for, as Figure 75 indicates, the effect on profits persists throughout the period studied. In contrast, the long-term debt is nearly unaffected until about the year 2000—after electrification is completed (see Figure 76). The changes in internal funds brought about by changed tax credits only affect the amount of outside funding needed to complete the investment in electrification of road and structures. The added debt for equipment is unaffected until after electrification, when the funds available internally for investment can again be invested in equipment. Consequently, peak debt and peak debt/equity ratios are little affected.

In summation, tax credit policies alone are unlikely to influence greatly the decision to electrify, although the effects on profits are clearly discernible. After all, the alternative tax credits affect profitability and profits for diesel operation much as they do electrified operation. Moreover, for diesel operation both debt and debt/equity ratios are affected throughout the period that the credits are changed because the available investment funds are always directed to equipment investment. Consequently, an increase in tax credits, for example, is beneficial in more ways for the diesel case than the electrified case, unless special rules are made for investment in electrified assets in the tax rules themselves.

Inflation and Interest Rates. Figure 77 indicates how lower inflation and interest rates reduce interest payments for the electrified case throughout the study period despite initially higher debt. After about 2005 the debt is reduced as well, and interest payments decline even faster. The debt is slightly higher initially when inflation is lower because older debts are discounted less in making the adjustment to constant 1975 dollars. But later, improved profits (see Figure 78) make more funds available internally (see Figure 79) and after electrification is completed those funds can be used to reduce the debt.

A higher direct tax credit ...

FIGURE 73. TAXES UNDER ALTERNATIVE INVESTMENT TAX CREDITS

... boosts profitability ...

FIGURE 74. RATE OF RETURN ON EQUITY UNDER ALTERNATIVE INVESTMENT TAX CREDITS

... and profits moderately

FIGURE 75. PROFIT UNDER ALTERNATIVE INVESTMENT TAX CREDITS

*Moderate debt improvement is felt after
electrification is completed*

FIGURE 76. LONG-TERM DEBT UNDER ALTERNATIVE INVESTMENT TAX CREDITS

*Higher inflation and interest bring higher
interest payments ...*

FIGURE 77. INTEREST PAYMENTS UNDER ALTERNATIVE RATES OF INFLATION AND INTEREST

... and lower profits

FIGURE 78. PROFIT UNDER ALTERNATIVE RATES OF INFLATION AND INTEREST

Internal funds available are greatly reduced

FIGURE 79. INTERNALLY AVAILABLE INVESTMENT FUNDS UNDER ALTERNATIVE RATES OF INFLATION AND INTEREST

The appearance of higher profitability is exhibited

FIGURE 80. RATE OF RETURN UNDER ALTERNATIVE RATES OF INFLATION AND INTEREST

Profits are improved with lower inflation and interest rates not only because of lower interest payments, but also because of slightly higher freight rates and net operating income. Freight rates, in turn, are slightly higher because the effect of regulatory delay in obtaining rate increases is less important with lower inflation. In contrast, profitability (i.e., return on equity or investment) is worse with lower inflation and interest rates (see Figure 80). Put another way, higher profitability is an illusion caused by higher inflation—high current dollar earnings are being compared with older dollars in equity or investment. Thus, because of the inflated apparent profitability, profits are a more reliable guide than profitability in deciding which financial climate most benefits electrification, or diesel operation. Lower inflation and corresponding interest rates result in higher profits, but the difference is not a deciding factor. In particular, because the difference is smaller during the critical years of financing electrification, the need for external funds is not strongly affected. However, given the delay in obtaining freight rate increases, much greater and persistent inflation would be clearly detrimental to railroads, regardless of whether electrification took place.

Summary of Effects of Alternative Assumptions

In summary, the financial strength and resources of the composite railroad in our scenario are quite sensitive to the basis adopted for adjusting freight rates and to the delay in implementing new rates. The principle of setting rates on the basis of ROI appears likely to make electrification attractive to railroad management and investors. The corresponding increase in freight rates necessary is relatively modest in terms of constant dollars, amounting to a slight increase in price to users of freight transportation services and, ultimately, the consumers generally. The effect of delay in setting new freight rates is large, and, as one would expect, is larger the greater the rate of inflation.

Financing alternatives influence the attractiveness of electrification less than do the rate-setting practices considered. In fact, the feasibility

of long-term debt primarily depends on the rate-setting practice—sole use of long-term debt appears to be feasible only when freight rates are set to yield a fixed ROI. This conclusion does not materially change when federal loans are considered; the loans just transfer the obligation to equipment debt after a few years. Of course, financial effects are obviated if the federal government buys and maintains the road and structure improvements necessary for electrification.

Finally, government policies that indirectly affect railroads, by determining investment tax credits, as well as influencing the rates of inflation and interest on debt, prove less important than the foregoing assumptions. Moreover, none of the policies considered would affect electrified operation per se by enhancing its attractiveness in comparison with continued diesel operation. Tax credits could be offered that favor investment in electrification, but the modest credits considered have relatively little effect during the difficult period of electrification of facilities.

Conclusions

In summary, the overall conclusions from our assessment of the economic impacts of electrification fall in three important areas:

- o Energy use
- o Setting freight rates
- o Financing electrification.

Energy Use

Electrification saves little energy; to precisely compare energy efficiencies of freight train operation before and after electrification requires information about speeds, acceleration, and the effectiveness of policies to conserve diesel fuel (reduced idling and the like). The difference between the energy content of

coal or other fossil fuel (or its nuclear equivalent) used to generate the electricity required and the energy content of the diesel fuel that would be replaced is small. The effect of the use rates assumed in this study is shown in Figure 81; 150 trillion Btu would be consumed in the base case electrification scenario in the year 2000, of which 17 trillion Btu would be used as diesel fuel for yard locomotives. This energy use compares with the 175 trillion Btu that would be consumed in diesel fuel in the base case diesel scenario, and with the 600 to 750 trillion Btu that would be consumed by all Class I railroads (including the links in the scenario). The largest use, 750 trillion Btu, would result if all Class I railroads were to grow in freight demand at the 1% rate assumed for the links in the scenario (except for the Burlington Northern coal-hauling link). The model results, together with the use rates assumed, indicate that about 3 to 4% of the energy use of all Class I railroads would be conserved.

FIGURE 81. ENERGY USED BY RAILROADS IN THE YEAR 2000
(Trillions of Btu)

Electrification of the links in the scenario would save some petroleum (about a billion gallons a year, or a little less than 1% of the mid-1978 import rate), if it is assumed that electricity is generated from non-petroleum sources of primary energy (refer to Figure 24). Presumably, that saving would reduce demand for imported petroleum, and with it the adverse balance of trade and balance of payments, erosion of national security, and the like. However, the saving in petroleum would not begin until 1985 and would not come into full effect until 1997. Moreover, the capital investment required to achieve the saving in petroleum use should be compared in detail with alternative capital investments and associated petroleum saving schedules. (Such a detailed comparison was not part of this study.)

On the other hand, as related in the first section of this chapter, if both diesel fuel and electricity are derived from coal, electrification of mainline freight operations on the links in our scenario would save considerably more energy. Approximately twice as much coal would be required to provide synthetic diesel fuel instead of electricity (refer to Figure 25).

Setting Freight Rates

In examining three approaches to setting freight rates, we found that estimates of impacts on the various stakeholder groups were more sensitive to freight rate-setting assumptions than to the other parameters studied. Figure 82 summarizes effects on the composite railroads ROI. The figure shows use of a rate-setting mechanism that allows maintenance of the rate of return at the level achieved in 1975 as a horizontal line, with only small fluctuations that stem from periodic rate reviews, inflation, and delays in obtaining new rates. We conclude that financing electrification would probably be feasible with that rate-setting alternative. (The 1975 level chosen for study was arbitrary; we do not imply that the level is reasonable or proper.)

FIGURE 82. RATE OF RETURN ON INVESTMENT FOR THREE RATE SETTING ALTERNATIVES

We found that relatively slight increases in freight rates (compared to rates in the electrification base case) were needed to maintain the rate of return, and that the resulting increase in funds available internally was sufficient to lower the requirement for outside capital from \$2.45 billion to \$1.4 billion (current dollars).

In contrast, the base case assumption that the historical relationship between operating revenues and operating expenses would continue indefinitely resulted in the lower curve in Figure 82. Profits and, consequently, internally available funds declined for an extended period. We conclude that financing electrification would be most difficult under this alternative because the need for outside capital is greatest and the ability to generate the income necessary to service the added debt or to pay dividends to additional stockholders is most impaired. Freight rates to users, however, were most attractive in this alternative because they are somewhat lower than for continued diesel operation.

The highest curve in Figure 82 relates to an assumption that rates for freight are set on the basis of the operating expenses that would have persisted if diesel operation had continued, rather than the expenses actually incurred after electrification. Such a rate schedule would make it economically possible for a competing railroad to maintain diesel service between the same two points. Freight rates are unchanged from the diesel base case, but profits and internally available funds are much larger. The internal funds are not available soon enough to reduce the outside capital required to a level lower than that needed in the constant-rate-of-return alternative, but equipment debt is reduced sooner. This alternative is more attractive for the railroads and least attractive for the users, who would have to pay the highest rates required of any of the three alternatives, although the rates would be no higher than for diesel operation. But, because of the continued divergence of rate of return and profits from historical levels, it is unlikely that the rate setting basis in this alternative could be maintained indefinitely.

The principal interest in the diesel cost based alternative may be that it corresponds closely with conventional ROI calculations that are performed from time to time by railroad managements considering electrification and by researchers in other studies. Frequently those studies have found electrification to appear attractive in its profitability, capital availability aside. Our analysis of this alternative would support those conclusions, but it also reveals problems in reconciling the implicit assumptions in those ROI calculations. Questions that should be answered regarding the plausibility of those assumptions are:

- o If rail links competing with an electrified link remain as diesel operations, would the railroads, through their rate bureaus, continue to be able to agree on the freight rates to be posted, and would those rates provide sufficient revenue for the diesel lines?
- o Would the ICC allow rates that provide sufficient revenue to diesel operations and that provide profits to electrified operations that far exceed historical levels?
- o If competing links also electrify, what basis would remain for establishing the costs of diesel operation?

- o Does the advantage of electrified operation depend on the existence of a competing diesel operation to justify profits that exceed historical levels?

Although railroads prefer the diesel cost based assumption, we doubt that regulatory commissions would long allow use of the fictionalized operating costs; instead, they will insist on use of the actual operating costs of electrified operations.

We also examined the effects of regulatory delay in approving new freight rates and found that delay in obtaining ICC approval of rate increases significantly reduced profits and long-term accumulation of equity, and that funds internally available for investment were materially reduced. Those significant effects occurred although the average reduction in freight rates were very slight, and were more severe the larger the rate of inflation.

Financing Electrification

Despite the attractive profitability that is usually found in studies of electrification of high-density freight routes, no mainline railroad routes have been electrified, and no intentions have been announced as of this writing to carry out an electrification project. The reason usually cited for not making the investment is a lack of capital. Competing capital needs (e.g., renovation and improvement of roadbed and other facilities) and the difficulty of attracting outside capital to an industry with an ROI that is low in comparison to other industries are the underlying factors.

Because financing electrification has thus far presented an impediment, we have placed particular emphasis in the study on examining various means of financing and have paid particular attention to the effects of the other alternative assumptions on the financing alternatives. We considered financing with common stock, long-term debt, and federal loans, and we considered the case of government ownership of the electrification facilities. In practice, combinations of those methods might be employed, but we examined them one at a time to single out the effects attributable to each.

We found that the attractiveness of either stock or debt financing depended strongly on the assumption about the basis for setting freight rates. With rates based on historical operating revenue/operating expense ratios, neither stock nor debt financing would appear attractive to prospective investors. Stockholders' ROE plunged for extended periods (several decades) in both cases, less so for debt financing because profits were not diluted by sale of stock. With debt financing used exclusively, debt/equity ratios loomed excessively large. But, with freight rates based on the maintenance of ROI, either financing method would be attractive to stockholders, although employing debt financing exclusively would raise debt/equity ratios sufficiently that the debt instrument might, in time, appear unattractive to prospective investors. Hence, stock financing, or some combination of stock and debt financing, would appear feasible if freight rates could be maintained that would assure a steady ROI. The freight rates that would be required appear to be feasible, only slightly higher (refer to Figure 52) than the rates that would apply under a cost basis (historical revenue/expense ratio), and somewhat lower than would apply with continued diesel operation (refer to Figure 27).

The federal loan alternative was found to be closely related to the long-term debt alternative. The difference in respect to financing is that the federal loans are assumed to be paid off from funds available internally, after the electrification program is completed. But payment of those loans in turn increases the equipment debt necessary to maintain operations. Overall, then, equipment debt is substituted for the long-term debt, with results similar to that alternative. However, rates based on a steady ROI result in federal loans being paid off 7 years sooner, and in equipment debt remaining essentially unaffected in comparison with the electrification base case. Hence, insofar as the long-term debt alternative is concerned, the attractiveness of the alternative to stockholders and to holders of debt strongly depends on the basis chosen for setting freight rates.

In the case of government ownership of the electrification facilities, the burden of financing and paying off the costs of electrification is lifted entirely from the railroads. Hence, there are no direct financial effects to

consider. Indirect effects could result, however, and would depend on the joint use arrangements made for the facilities. These inherent effects were not studied in detail, however. Clearly, the interests of the privately held railways, the shippers, and the taxpaying public would have to be considered.

Applications of Study Results

Because the electrification scenario included links from several railroad companies, comprising a composite railroad company, the results are not immediately and directly applicable to any one company. The illustration of the Santa Fe links showed that such an application should not be made; rather, the model should be run separately for each company. Nonetheless, study of the composite is useful in understanding the interrelations among the various stakeholders, and in understanding the sometimes conflicting assertions made about the attractiveness of electrification to railroads, to the public, and to other stakeholders.

The model developed in this study can be further applied to other composite electrified or diesel networks; can be used to consider other alternative assumptions about the same parameters we highlighted or other parameters included in the model and can be applied to the operations of all, or any part, of a railroad company.

VII WHAT ARE THE SOCIAL AND ENVIRONMENTAL ISSUES THAT ARISE FROM RAILROAD ELECTRIFICATION?

Introduction

The social and environmental impacts related to railroad electrification will include such direct results of electrification as providing the labor needed to maintain and operate electric locomotives and catenaries. Support industries will also be affected, particularly those whose output will be increased by the switchover to electricity (e.g., companies producing electric equipment and catenaries). Residents in the vicinity of the electrified tracks may note differences in diesel and electric operations, particularly changes in noise levels, air quality, electromagnetic interference, and safety. Electrification could also result in changes in the amount of taxes paid.

If considered in isolation, many of these impacts may seem insignificant. When combined, however, their overall effect may become apparent—especially when such combination results in many indirect impacts.

The generalized social and environmental issues discussed below strictly apply only to the freight mainlines. Specific effects that do occur will, of course, depend on the actual location of a line, the traffic on that line, the nearby population, and social and environmental patterns of the area.

Labor

The switch from diesel-electric to electric locomotives will affect railroad and support industry personnel, to the extent that an individual's job is changed or eliminated by electrification. For example, the workers needed to construct the

catenary constitute one support industry group that will benefit from new jobs created by electrification. The impacts on railroad labor are summarized in the tabulation below:

REQUIRED RAILWAY EMPLOYEE MAINTENANCE SKILLS

	<u>Electrified Routes</u>	<u>Competing Diesel Routes</u>	<u>Overall</u>
Diesel repair	Less	Less	Less
Electrical repair	More	Less	More
Catenary	New	None	New
Track and Route	More	Less	Same

Electrification will decrease the number of engine maintenance workers needed and will require new skills for those still employed. Maintenance workers will decline in numbers for several reasons: Electric locomotives have fewer service failures, longer periods between inspections, and lower maintenance requirements, which make them more available overall for service than their diesel-electric counterparts. Therefore, fewer locomotives will be needed to do the same amount of work. (This aspect will also reduce the maintenance required.)

We will witness, therefore, not only a decline in the number of maintenance workers but also a change in the skills required. Railroads will need (1) to retrain workers already employed, or (2) hire others who have these necessary skills. If the railroads choose option (2), numerous locomotive maintenance workers will lose their jobs.

Another area of maintenance that will be affected is locomotive cleaning. Because an electric locomotive does not burn fuel, it does not get coated with the fuel, lubricants, and combustion products as a diesel locomotive does. Much of current locomotive cleaning has to be carried out by hand. About twice as much labor is expended on diesels as on electrics (Calder, 1977).

Fueling

The number of employees that fuel diesel engines will substantially decline. Diesel engine use on electrified links will be almost entirely relegated to switching yards and branchlines. Therefore, not only will the numbers of diesel locomotives decline, but those remaining will find limited use.

New Job Opportunities

The majority of the new jobs in the railroad companies will be associated with maintenance of the new facilities and equipment--in particular, electric locomotives, catenaries, and substations. (The maintenance of electric locomotives is discussed above.) The maintenance and regular surveillance of the catenary and substations may require a maintenance crew of as many as 16 people for each 100 miles of track.

Electrical Support Industries

A change as substantial as the switch from diesel-powered to electric-powered locomotives will have significant effects for four major categories of industries involved: construction, equipment and supplies, locomotive manufacturers, and utilities.

The construction industry will supply workers to build the catenary, although this work will be temporary. The equipment and supply industry, as well as locomotive manufacturers, will require large staff increases. As electrification is completed, the demand for locomotives will level off, as illustrated in Figure 13. The equipment and supplies industries will provide parts for repairs but demand for these supplies will decline from the level needed during construction and start-up. With the decline in demand, staffing requirements will also decrease.

During electrification, utilities will need a substantial number of temporary workers to build feeder lines, substations, transmission lines as necessary, and possibly new generating facilities. With the completion of the electrification process, permanent maintenance crews will be required.

Diesel-Oriented Industries

The number of diesel locomotives operating along electrified links will decline markedly, resulting in a substantial curtailment in orders for diesels, as well as in the release of surplussed diesel locomotives. Figure 15 showed the impact on the diesel market. The decline in diesel locomotive production will result in fewer employees in the factories that produce these locomotives.

Diesel fuel suppliers will also be affected, given the decline in demand for their product. Some demand for diesel fuel will remain, however, because diesel locomotives will operate in the switchyards and on branch lines, but it will be substantially less than previous purchases. The decrease in business will result in fewer workers required in this industry.

Grade Crossing Users

Vehicle and truck drivers, as well as pedestrians and bicyclists, who cross railroad rights-of-way already have to wait for trains periodically. The electrification of mainline freight routes will affect both those using grade crossings on the electrified links and those who use the grade crossings on diesel routes.

The catenary will pose an added risk for some grade crossing users. Although the catenary will be strung higher than most highway overpasses, tall vehicles such as cranes could come into contact with 50-kV catenaries. Automobile operators, on the other hand, will never contact the catenary during

normal driving unless the catenary falls because of sabotage, weather, or another accident.

The railroad model applied to our scenario predicts increased traffic along the electrified line from the transfer of traffic from competing diesel routes. The increased number of trains may make accidents more frequent. An FRA study shows that accidents involving motor vehicles increased between 1975 and 1976 (FRA, 1977b). The FRA is concerned about a potential increase in accidents at grade crossings. Accidents at crossings already account for 65% of fatalities occurring in railroad accidents (OTA, 1978). Note that accidents at the grade crossings of competing diesel lines may decline in compensation, but the net change will ultimately depend on the traffic at the various crossings and on population and the number of crossings.

According to a study by the California Public Utilities Commission, automatic warning devices are quite effective in reducing vehicle-train accidents and, therefore, casualties at railroad-highway grade crossings (CPUC, 1974). The study concluded that the installation of automatic crossing gates, on the average, results in 70% fewer vehicle-train accidents per year with 48% fewer casualties in those accidents that do occur. For the routes in our scenario, automatic warning devices could significantly reduce or mitigate potential accidents.

Traffic backups already occur at grade crossings. The frequency of occurrence and the length of wait depend on the number of trains, the daily schedule, and the length of the train. Electrification will tend to worsen backups, thereby increasing motor vehicle operating costs that result from speed reductions when stopping for a train, as well as the costs associated with acceleration back to normal speed.

Travel time will also increase. The significance of the delays will depend on the length of the delay and the occupants' schedules. Delays of commercial vehicles will reduce the productivity of both the vehicle and the operator. On the other hand, people who are sightseeing or driving to a recreational destination will tend to be less concerned with delays (SRI, 1975).

Automobiles, trucks, and buses idling at the crossing, or slowing down to cross and then accelerating, emit more pollutants than if they continued at a steady, slower speed (SRI, 1975). The increased number of trains could, therefore, result in a further increase in air pollutants that will affect both drivers and other people in the vicinity of the tracks. The impacts on grade crossing users are summarized in the following tabulation.

	<u>Along Electrified Routes</u>	<u>Along Competing Diesel Routes</u>	<u>Overall</u>
Catenary hazard	New	None	New
Accident potential	Higher	Lower	Higher
Traffic backup	More	Less	Same
Air pollution	More	Less	Same

Neighbors

This stakeholder group consists of those living and working near both electrified and competing diesel routes, those living and working along the transmission line rights-of-way, and those near the electrical generating facilities. Most of these people are already affected by railroad operations, electric transmission lines, or by generating facilities. To some degree, railroad electrification will change existing air quality, noise levels, aesthetics, and safety. New impacts may also result from such effects as electromagnetic induction along the routes proposed for electrification. The impacts on neighbors discussed below are summarized in the following tabulation:

<u>Environmental Parameter</u>	<u>Along Electrified Routes</u>	<u>Along Competing Diesel Routes</u>	<u>Along Power Lines</u>	<u>Overall</u>
Air Quality	Improved	Improved	Unchanged	Improved
Noise	Decreased	Decreased	Increased	Decreased
Aesthetics	Degraded	Unchanged	Degraded	Degraded
Safety	Degraded	Improved	Degraded	Degraded
Electro- magnetic	Degraded	Unchanged	Degraded	Degraded

Air Quality

Diesel locomotives emit air pollutants as they travel along the mainline right-of-way, resulting in a "line-source" of pollutants. Electrification would transfer the source of pollutant emission to the electrical generating facility providing power for rail operations. (Electrical locomotives themselves are not a source of air pollution.) Diesel locomotives, operating in the switching yards, would still comprise a "point source." The point source configurations of electric power plants stand in marked contrast to current mainline diesel locomotive operations. Electrical power plants can often be located in areas remote from population centers and are more amenable to source emission controls than mobile sources such as diesel locomotives (Cooper, 1976). This is a particularly important difference for urban areas affected by air pollution problems.

Railroad operations produce four significant air pollutants: sulfur dioxide (SO_2), particulate matter, nitrogen oxides (NO_x), and hydrocarbons. For consistency with emerging U.S. energy policy, the electricity generated for electrified operations is assumed to be produced from coal.

Coal types and emissions data are taken from an earlier SRI study (Dickson et al., 1976). The control efficiency for removal of SO_2 from flue gas at electric power plants was assumed to be 90%, and for particulates, 99.5%, in that study. With route electrification, particulate emissions will substantially decrease from those produced by diesel operation. Figure 83 compares the particulate emission levels of diesel operation, with those of electric operation. Diesel locomotives, when confined to switching yards, contribute a significant proportion to the (lesser) quantity of particulate emissions; moreover, as indicated above, they become a point source of pollutants because their area of operations is limited.

NO_x emissions will also decline substantially (see Figure 84). With electrification, the remaining diesel operations will contribute less substantially to the concentration of this pollutant than to particulates.

The most dramatic drop will occur in hydrocarbon emissions (see Figure 85) because electric generation produces few hydrocarbon emissions. Rather, the diesel locomotives, operating in the switching yards will contribute a large majority of railroad-related hydrocarbon emissions.

SO₂ emissions resulting from electrification will depend on whether high- or low-sulfur coal is used to produce electricity. If low-sulfur Powder River coal from Wyoming and Montana is used to generate the electricity for operation, fewer emissions than from diesel operation will result (see Figure 86). If, instead, a high-sulfur coal such as Illinois coal is used to generate the needed electrical power, SO₂ emissions would substantially increase when compared with diesel operation, as shown in Figure 87.

If the lines are electrified, the net amount of pollution produced will decline for every pollutant, except perhaps SO₂. However, pollutant emissions will decline along mainlines and increase in the areas where the electricity is generated.

Noise

The noise produced by railroad operations was also considered. As Figure 88 shows, diesel trains are much noisier than electric trains at low speeds. The electric locomotive is particularly quiet at slow speeds, a significant difference because many cities require that trains travel slowly within city limits.

The railroad model applied to the scenario predicts an increase in traffic along the electrified route that is mainly due to the switchover of some traffic from competing diesel routes. The change in traffic will affect noise levels along both the electrified as well as the competing diesel lines. Noise along diesel routes will decline because of reduced traffic. The noise level along the electrified route will decline, offset to some extent by the increased number of trains.

FIGURE 83. ANNUAL AVERAGE PARTICULATE EMISSIONS

FIGURE 84. ANNUAL AVERAGE NITROGEN OXIDE EMISSIONS

FIGURE 85. ANNUAL AVERAGE HYDROCARBON EMISSIONS

FIGURE 86. ANNUAL AVERAGE SULFUR DIOXIDE EMISSIONS – POWDER RIVER COAL

FIGURE 87. ANNUAL AVERAGE SULFUR DIOXIDE EMISSIONS — ILLINOIS COAL

FIGURE 88. NOISE LEVEL OF TRAINS AT 100 FT.

The transmission lines supplying energy to the electrified rail line will slightly increase the noise level of the areas adjacent to the transmission right-of-way, but only when rain, fog, or snow occur in the area.

Aesthetics

Railroad operations have already visually intruded on environmental aesthetics. The addition of the catenary, substations, and additional transmission lines will result in some further visual aesthetic degradation. The extent of the impact will depend on several variables; one of the most important will be the number of people who view the visual change. The aesthetic impact of a catenary constructed in an isolated low-population area will affect fewer people than one constructed within a highly populated residential area. Another variable affecting the aesthetic impact will be the land use near the right-of-way. The aesthetic impact will be greater in a relatively pristine natural area than it will be in an area devoted to heavy industrial uses.

Construction practices could also decrease visual intrusion. Visual screening around transmission substations would reduce their visual intrusion, as could selection of materials used for substation construction. The impact of the additional transmission lines could be lessened by placing them out of view of passersby.

Safety

Safety of workers and the public is already an important issue for railroad operations. The FRA's yearly report on grade crossing accidents and incidents indicated that railroad accidents increased between 1975 and 1976. (Due to changes in reporting requirements as of January 1, 1975, data collected after this time are not directly comparable to those collected in previous years.) The hazard from trains exists all along the right-of-way and not just at grade crossings, especially for those living and working in proximity, including railroad maintenance crews. Electrification will slightly increase the probability of accidents because more trains will pass along the route.

The increase in track maintenance that will be required with electrification could offset the probable increase in accidents. An Office of Technology Assessment report (OTA, 1978) indicated that from 1966 to 1974 track-caused train accidents increased by more than 100% per ton/mi. (It is clear that track-caused accidents continue to increase, although 1975 changes in data reporting make comparison with earlier data difficult.) The increase is related both to an extensive deferral of maintenance and to increased axle loading. Accidents will ultimately depend more on track maintenance than on the issue of electrification.

The overhead catenary with its high voltage will also introduce a safety risk. Maintenance crews and construction workers will have to be informed of the risks, and instructed about the procedures for normal operations and emergency conditions. The catenary can also endanger others--particularly those trespassers who climb on the cars or on the catenary support structure itself (Swanson, 1977).

The quieter electric locomotive also poses a hazard to workers and pedestrians alike. Reportedly, at times, electric trains have come quite close to workers before they realize the train is approaching; sometimes a whistle blowing at grade crossings is the only warning sound to alert workers. In comparison, diesel locomotives are so noisy that the workers have sufficient time to move away from the tracks.

Electromagnetic Interference and Shock Hazards

High voltage gradients exist between the catenary and rails, and a high electric current can flow along them when electric locomotives are drawing large amounts of power. Metallic conductors nearby can become charged by this voltage and current, as can anything that comes in contact with the conductors. Those effects are associated with any high-voltage transmission of electricity, and have been well documented (Scott-Walton, 1979). In addition to those effects

associated with high-voltage transmission, the load current drawn by electric locomotives can also cause unintended effects both in the power distribution and generation system itself, and in equipment that is connected to the same power system by other commercial customers or that is used near the distribution system or catenary.

High-voltage transmission effects can be attributed physically to two sources:

- o Electrostatic induction—Because of capacitive coupling, voltages are induced on conductors that are close to a high voltage wire and are ungrounded, regardless of the flow of current in the wire. Several hundred volts could be induced in ungrounded wires, metal roofs, or metal fences along the right-of-way.
- o Electromagnetic induction—Voltages are induced in conductors by magnetic fields generated when current flows in the catenary and rails. If a wire or other conductor is grounded at one point, a potential of several hundred volts could appear at a point remote from the first (as far as several hundred yards away).

If sufficiently high voltages are induced in a conductor by either electrostatic or electromagnetic induction, interference may be caused in trackside communications systems and signaling systems attached to the conductor. As a result, extensive modification of these systems is usually required when electrification is undertaken. (The associated costs were included in our analysis.) Other nearby private or commercial systems may also be affected. In some cases, a shock hazard may be created if proper grounding or shielding precautions are not undertaken. Investigation for such potential hazards is a routine but necessary part of an electrification project.

The characteristics of the load current drawn by a modern (rectifier) electric locomotive can also cause system interference (Ross, 1971). Some kinds of interference directly affect the power distribution and generation system, whereas they affect other power customers indirectly:

- o Phase current imbalance—The large, single-phase load drawn by electric locomotives can cause problems in the generating

equipment of the utility. Careful system design, including use of all three voltage phases in the catenary system as a whole, can keep imbalance within limits.

- o Voltage imbalance—The large single-phase load can cause voltage imbalance between phases that can overload or damage three-phase equipment connected to the system. Again, careful system design is necessary to limit the imbalance.
- o Sudden load impact—Effects from the two kinds of interference listed above are made worse when a locomotive consist drawing a heavy load crosses the gap between two supply points on the catenary with different voltage phases. This impact can usually be tolerated if the system has been designed to meet the voltage imbalance criterion.

The chopped current waveform produced by the power conditioning equipment on the locomotive, as it is throttled back to less than full power, also can directly affect other customers nearby on power distribution or communications systems. Higher harmonics of the supply frequency (60 Hz) can appear in the load current, causing unintended effects, such as noise, in electronic equipment elsewhere on the power distribution system or in equipment that is located close enough to the catenary that electromagnetic induction of the harmonics can occur. Electromagnetic induction has more effect the higher the frequency, and significant noise levels can be introduced at far lower voltages (i.e., at greater distances) than those that cause effects at the fundamental frequency. These effects are controlled by proper shielding and grounding, which are also used to control electromagnetic induction of the fundamental (60-Hz supply) frequency.

Taxpayers and Government

Railroads, like all other utilities and industries, are taxed by state and federal governments, as well as by local governments in some states. Railroads pay property, income, capital stock, sales, and use taxes. Electrification will affect the taxation of the railroad companies in many ways.

Property Taxes

Railroad electrification will affect tax receipts in several ways. First, the tax liability of the railroad undergoing electrification will change. Because of the large investments required in road and structure (as shown in Figure 35), the electrified railroad will be liable for increased local property taxes.

The value of property adjacent to electrified railroads will vary with the property's use. Because commercial and industrial property (e.g., warehouses or manufacturing plants) will benefit from the increased quality and frequency of electrified service, and from the expected decrease in freight rates, its value will probably appreciate as will its property taxes. Conversely, residential property adjacent to electrified tracks will probably become less valuable, and liable for less tax, because of the increased frequency of trains (even quieter ones) and the visual intrusion of the catenary structures. The extent to which these two tax effects offset one another will depend on the mix of land uses along a given electrified link.

On the other hand, property owners along competing railroads that continue diesel operation will witness the reverse effect for their taxes. The decreased frequency of service will lower commercial and industrial property values, whereas it will raise residential property values because noise from trains will decrease.

Income Tax

Electrification will affect the profitability of the companies in question. Although with our base case scenario railroad profits decrease after electrification, the extent of any increase or decrease will depend in general on the particular assumptions (as was shown in our sensitivity analysis). In the base case, the amount of taxes paid would obviously decrease, whereas if the diesel cost-based rate-setting assumption were proved valid, profits would substantially increase eventually. Then taxes paid by electrified railroads would increase. The investment tax credit provisions will also affect the quantity of taxes paid.

VIII WHAT ARE THE GOVERNMENTAL AND INSTITUTIONAL ISSUES THAT ARISE FROM RAILROAD ELECTRIFICATION?

The federal government has taken a strong interest in railroad matters, especially in recent years when it has had to intervene to deal with the financial difficulties of several major railroads. The federal government has taken the position that a workable and efficient rail network is vital to the nation's interest "to meet the needs of commerce, the national defense, the environment, and the service requirements of passengers, U.S. mail, shippers, states and their political subdivisions, and consumers."* Policy declarations accompanying recent railroad legislation also mention land use, energy efficiency, energy conservation, resource allocation, safety, and cost per ton-mile of movement.†

Relation of Electrification to Other Issues

The nation's railroads could help reduce U.S. petroleum demands: Some freight now carried by truck could be hauled more efficiently by rail; existing diesel rail operations could be made more efficient; and the basic motive fuel could be shifted from petroleum to coal (or nuclear) through large-scale electrification. National security and U.S. dependence on foreign petroleum, although not specifically addressed in the 4R Act, are also issues of concern.

Lowering imports would reduce our strategic vulnerability to curtailment of critical fuel supplies by hostile or politically unstable oil-producing nations.

*Regional Rail Reorganization Act of 1973 (HR Act) as amended P.L. 93-236, 87 Stat. 958, section 101 (a) (3).

†See P.L. 93-236, 87 Stat. 958, section 101 (a)(5), and Railroad Revitalization Reform Act of 1976, P.L. 94-210, 90 Stat. 31 (Feb. 5, 1976), section 101(a).

Lowering oil imports would also help rectify balance of payments problems. In 1977, for example, the U.S. purchased \$45 billion worth of oil from abroad largely contributing to a net trade deficit of \$27 billion, and the problem has been worsening (Business Week, 1978a). This, in turn, contributed to a decline in the value of the dollar abroad, reducing purchasing power for Americans already troubled by the effects of an inflationary economy.

A federal policy that encourages electrification of the nation's mainline rail system is but one of several alternatives for decreasing the United States' energy dependence. Increasing efficiency to reduce petroleum use represents one way; another is powering diesel-electric locomotives with fuel refined from synthetic crude oil derived from coal. However, coal liquefaction technology is capital-intensive (over \$1 billion for a 100,000 B/D plant), and social and environmental costs are also associated with the technology (Dickson et al., 1976).

Although reducing petroleum imports may make the nation more secure, rail electrification carries with it its own risks. Electric power plants, substations, and the catenary network would be vulnerable to sabotage. Furthermore, the electric power plants themselves present likely targets for nuclear attack because they constitute a more centralized power source than elements of the widely dispersed petroleum refining, storage, and distribution system. Moreover, nuclear blast would generate an electromagnetic pulse that would be picked up by the catenary and transmitted to substations and to locomotives on the line. This pulse could severely damage electrical equipment, increasing the time required to place the domestic supply system into operation again.

A driving force for profitable electrification of certain freight routes in our electrification scenario is the large amount of western coal expected to be produced beginning in the late 1980s. Although the scenario has this coal carried by the railroads, coal slurry pipeline companies are actively seeking to enter the coal-carrying market and are lobbying at the state level and in Congress for

power of eminent domain. Congress has not passed eminent domain legislation, but it is now considering HR 4370, The Coal Pipeline Act of 1979, a bill that would grant eminent domain authority to coal pipeline companies. The most recent energy "crisis," precipitated in part by events in Iran, will likely make this concept attractive to the Congress. Pipeline companies could also obtain the necessary authority from those states through which a pipeline would pass. Apparently this has been accomplished by ETSI (a coal pipeline consortium) for its proposed slurry pipeline from Wyoming to Arkansas. The railroads, whether they electrify or not, are relying on heavy coal traffic to secure their financial future and are thus concerned about this competitive threat.

Electrification of mainline rail freight routes, at an expense of about \$4.7 billion (current dollars) would reduce oil imports by only about 1%. However, electrification could also help the railroads become more productive and more competitive with other transport modes. Enhanced competitiveness would increase railroad freight business and revenues, thereby making the railroads more attractive to outside investors. The financially sound and operationally efficient railroad system that would result could satisfy many national railroad goals.

Federal Support for Transportation

Federal support for electrification of the mainline freight rail routes could take any of the following forms:

- o Funds for research and development (R & D)
- o Investment tax credits
- o Loan guarantees
- o Low-interest loans
- o Grants backed by treasury bonds
- o Federal ownership of the catenary
- o Federal ownership of the catenary and right-of-way.

Money and loan guarantees are provided for in the 4R Act. Under present law investment tax credits are available to all businesses, including the railroads. The other methods of federal support listed are merely possibilities; they will be discussed further in this chapter.

Considerable difference of opinion exists about the degree of federal support that has been given to rail, highway, and water transportation modes. The railroads maintain that the trucking industry is the beneficiary of government largesse in the form of highway construction and maintenance funds -- especially those spent on the interstate highway system. The trucking industry insists that trucks pay their fair share of highway costs through highway user fees. The railroads also maintain that waterborne commerce is, in effect, subsidized through U.S. Army Corps of Engineers' dredging and maintenance of navigable waterways, and through construction and maintenance of locks. Only recently has Congress imposed a user charge on waterborne commerce, the first such charge in the history of U.S. waterborne commerce.*

The trucking industry and the water transport industry, on the other hand, point out the history of government support for the railroads, particularly the vast land grants given to the railroads to stimulate initial construction and expansion. Large tracts of those initial grants of land proved to contain recoverable coal reserves. The trucking industry and the water transport industry also note the substantial federal contribution in recent years to the Railroad Employees Retirement Act Fund.

However, past federal contributions to all modes aside, the present need to preserve a workable transportation system that incorporates the best attributes of the several modes is more important. In this regard, it is also of interest to review the federal regulations of the various modes.

* P.L. 95-502

Regulation of Commerce

The ICC was created in 1887 by the Act to Regulate Commerce.* The ICC was to oversee the rates and rate practices of interstate common carriers engaged in transportation by railroad. In the Transportation Act of 1920⁺ Congress established a rule of ratemaking intended to assure a fair return to the carriers; that Act also authorized the ICC to fix minimum or precise rail rates. Regulation was extended to motor carriers in 1935^{**} and to water carriers in 1940,[#] but in the process Congress exempted private carriers, and commercial shipping of agricultural and bulk commodities. Thus, the railroads came to be the only universally regulated transportation mode, a situation that has hurt their competitive position. That railroad companies are unhappy with this situation is evidenced by the following statements made by railroad officials:

...it is inconceivable that we can have a situation where coal moving (by barge) between a coal mine on the Ohio River and a powerplant on the Mississippi River is totally exempt from regulation, that waterways can operate or can charge whatever they can get for moving that coal, yet coal that moves (by railroad) from a coal mine in Wyoming ... to a powerplant in Texas is totally subject to regulation and to all the rules of suspension, investigation, and so forth.++

*24 Stat. 379 (1887)

⁺41 Stat. 474 (1920)

^{**}Motor Carrier Act, 1935, 49 Stat. 543 (1935)

[#]Transportation Act, 1940, 54 Stat. 929 (1940)

⁺⁺Statement of Benjamin F. Biaggini, Chairman of the Board and Chief Executive Officer, Southern Pacific Railroad, Congressional Symposium: Railroads -- 1977 and Beyond: Problems and Promises, House Subcommittee on Transportation and Commerce, 95th Cong., 1st Sess., Dec. 14 and 15, 1977, p. 49.

and

...we simply are destroying the rail system by permitting this mixed bag of regulations where really substantially all of your highway traffic is unregulated.*

Another railroad spokesman described the regulated rail common carrier burden as follows:

We are at a serious disadvantage when our competitors do not have to publish rates; charge anything the market can bear; do not have the responsibilities to provide this service; have no obligations to provide service on demand, or any of the other common carrier obligations that the railroads have to operate under. Clearly, it creates a differential burden.+

A study for Congress by the Office of Technology Assessment stated that "public policy toward other modes has had an enormous adverse impact on the viability of U.S. railroads" (OTA, 1975).

Responding to the poor financial condition of many railroads and to repeated complaints of unresponsive regulation, Congress passed the 4R Act.** The Legislative history accompanying the 4R Act stated that the Act was to "eliminate needless or harmful regulatory restraints on railroads" by prescribing "ratemaking practices which will encourage effective competition and protect customers."# The key functions of the 4R Act are to:

*Statement of Benjamin F. Biaggini, Chairman of the Board and Chief Executive Officer, Southern Pacific Railroad, Congressional Symposium: Railroads -- 1977 and Beyond: Problems and Promises, House Subcommittee on Transportation and Commerce, 95th Cong., 1st Sess., Dec. 14 and 15, 1977, p. 49.

+Statement of John W. Snow, Vice President for Government Affairs, Chessie System, Congressional Symposium: Railroads -- 1977 and Beyond: Problems and Promises, House Subcommittee on Transportation and Commerce, 95th Cong., 1st Sess., Dec. 14 and 15, 1977, p. 131.

**Public Law 94-210

#House Report 94-781, 94th Cong., 2nd Sess., 1976, p. 134.

- o Amend the provisions for Conrail
- o Fund a major rehabilitation program for the Northeast rail corridor
- o Provide for redeemable preference shares and loan guarantees
- o Expedite the merger process
- o Eliminate discriminatory taxation
- o Establish more freedom in the ratemaking process
- o Provide a method for eliminating uneconomical light-density branch lines.

Insofar as electrification is concerned, the most interesting of these 4R Act provisions is the one related to ratemaking; it was concluded in Chapter VI that profitability for electrified rail freight lines will be quite sensitive to rate setting. Moreover, if railroads could charge freight rates that give a reasonable rate of return on the electrification investment, electrification, at least for the financially stronger railroads, could be accomplished with minimum government assistance.

The 4R Act sought to enable railroad management to respond more quickly to changing market conditions, and to be more creative and flexible in competing with other transportation modes. The ratemaking tools that Congress fashioned are found in Title II of the 4R Act. Section 202 provides ratemaking freedom: A rate proposed by a railroad will be assumed to be just and reasonable, and, hence, beyond the control of the ICC unless the Commission finds that the carrier has "market dominance" over the transportation service.

The Act defines market dominance as the absence of effective competition. Section 205 goes to the issue of overall adequate revenues, as follows:

(The ICC) shall...develop...reasonable standards and procedures for the establishment of revenue levels adequate...to cover total operating expenses...plus a fair, reasonable, and economic profit or return (or both) on capital....

Of course, these two sections are complementary. Profit-making rates freely set pursuant to Section 202 would go far toward achieving vitality. The stumbling block, as far as the railroads are concerned, is the "market dominance" language in the legislation; they point to ICC actions that, from their perspective, render the ratemaking freedom illusory. The ICC had declared that a rebuttable presumption of market dominance will arise (1) when the proponent carrier has handled 70% of the traffic involved; (2) when the rate exceeds variable costs by 60%; and (3) when a shipper or consignee has made such a substantial investment in rail-related equipment that it is impracticable to switch to another mode.*

The Department of Justice, believing that the ICC's position was improper and contrary to the intent of Congress, filed a brief before the U.S. Court of Appeals for the District of Columbia in challenge to the ICC Position. In part, the brief stated that "the ICC's market dominance rules will...trigger a presumption of rail market dominance with respect to most rates likely to be disputed, and will afford the railroads virtually no greater rate flexibility than they enjoyed in the past...."⁺ The railroads believe that, at the least the ICC should establish a parallel presumption that says market dominance does not exist under certain conditions; not having such a presumption has created uncertainty for the railroad industry. "The industry finds it impossible to know when it is free to price and not free to price."**

Others take the position that ratemaking freedom alone will not give the railroads financial health. A spokesman for the United States Railway Association points out that problems exist with the roadbeds, freight car use, and with

*ICC Ex Parte No. 320, Oct. 1, 1976

⁺Although the court found in favor of the ICC, the Commission has agreed to reopen the docket on the issue of market dominance.

**John W. Snow, op. cit., p. 126

bottleneck rail terminals -- conditions that undermine reliable service.* Clarence Braddock of the FRA echoed this position at our workshops on electrification of railroads where he asked why the government, or the railroads, should pour billions of dollars into an electrified system whose roadbeds, terminal operations, and freight car use are generally inadequate for present diesel operations.+ Clearly, overhaul of these parts of the rail system is necessary for efficient operation of the diesel system and would be a prime requisite were electrification to proceed. Only then could the inherent performance advantages of electric locomotives be put to use, and the substantial investment justified.

Labor Issues

Railway labor could also reduce the benefits of electrification. A change in skills would be required in going from a diesel system to an electrified system. Catenary maintenance would constitute a new hiring area, whereas diesel powerplant repairmen would be replaced by maintenance workers with electrical skills. Coast-to-coast service of multicar electrified freight trains could be inhibited by railway unions' reluctance to alter existing labor practices to accommodate to the requirements of this new system.

Antiquated work rules that are tied to an earlier time and technology (e.g., one day's pay for every 100 miles of train travel) undermine railroad efforts to become more efficient and competitive with other transportation modes. Railway unions and railway management will thus have to face the issues raised by such a transition. Some of the diesel-engine maintenance personnel could be retrained or

*Statement of William K. Smith, Acting Chairman, United States Railway Association, Congressional Symposium: Railroads -- 1977 and Beyond: Problems and Promises, House Subcommittee on Transportation and Commerce, 95th Cong., 1st Sess., Dec. 14 and 15, 1977, p. 6.

+Remarks of Clarence Braddock, SRI International Workshop on Railroad Electrification, Fredericksburg, Virginia, April 19, 1978.

reassigned to parts of the rail system that continue to rely on diesel power (e.g., classification yards where diesels remain in service). The federal government could encourage labor cooperation by liberal refinancing of the Railroad Retirement System (TFRP, 1973). Such financial assistance would allay railway labor's concerns about retirement and long-term security, and could serve as a quid pro quo to make labor more willing to accept work rule changes that complement electrification.

Railway labor spokesman acknowledge that their security is highest when the railroad industry itself is economically secure. In fact, negotiations between railroad management and labor from 1971 through 1976 resulted in reducing the number of railroad employees by about 22,500, with a third of this reduction occurring when the firemen-manning problem was resolved.* In noting labor's response to creative cost-savings, the United Transportation Union (UTU) points to two examples: one agreement with the Chicago and Northwestern Railroad allows trains to run with short crews, taking into consideration safety factors and train length; the second agreement, the so-called "slingshot train" concept of the Illinois Central Gulf Railroad, lets unit trains run between Chicago and St. Louis with only an engineer and a conductor.* Still another example may be seen in the case of the Chicago, Milwaukee, St. Paul and Pacific Railroad. In April 1978, the UTU and the Chicago, Milwaukee, St. Paul and Pacific agreed to reduce crew sizes gradually (by eliminating one brakeman), coupled with increased payments per trip to each crew-member on reduced-crew runs, and payments into an employee productivity fund (Business Week, 1978b). In the "St. Louis Project" of the Task Force on Rail Transportation, 24 experiments designed to achieve greater productivity succeeded in reducing the average time a car spent in the St. Louis Terminal from 18 hours to less than 12 hours.† About one-half of the

*Statement of George W. Legge, Vice President, United Transportation Union, Congressional Symposium: Railroads — 1977 and Beyond: Problems and Promises, House Subcommittee on Transportation and Commerce, 95th Cong., 1st Sess., Dec. 14 and 15, 1977, p. 41.

†F. J. Zamarioni, Vice President, United Transportation Union, Congressional Symposium: Railroads — 1977 and Beyond: Problems and Promises, House Sub-Committee on Transportation and Commerce, 95th Cong., 1st Sess., Dec. 14 and 15, 1977, p. 81.

experiments required existing labor agreements to be waived.⁺ Thus, labor sees itself as responsive to railroad management problems, and as prepared to serve an electrified mainline freight system as well.

Federal Role

As discussed earlier, the federal government could go beyond guaranteeing loans. It could itself become the lending institution. However, this federal role would create problems for other financial institutions that lend money to the railroads because the federal role tends to distort the market. Federal loans typically stipulate that, in the event of insolvency, the government will be paid off in full first. The Penn Central and the bankruptcy of other eastern railroads highlighted this problem and left mixed feelings about the federal role in the financial community.[#]

The money necessary for electrification might be obtained more directly through direct grants to the railroads (with the funds earmarked for electrification). These grants could be backed through the sale of long-term U.S. Treasury bonds. Another method entails the federal government acquiring ownership of or access to the right-of-way of principal freight routes and constructing, owning, and leasing (or operating) a catenary system.

Such an approach, which resembles federal ownership of highways and waterways and federal control of the airways, would put the railroads on a more even footing with the other transportation modes. It would also mean that the railroads would not have to make large outlays of money or borrow the large sums required for electrification. The burden would be borne by the federal government, with the reasoning that it is in the national interest to do so.

⁺F. J. Zamarioni, Vice President, United Transportation Union, Congressional Symposium: Railroads -- 1977 and Beyond: Problems and Promises, House Sub-Committee on Transportation and Commerce, 95th Cong., 1st Sess., Dec. 14 and 15, 1977, p. 81.

[#]Remarks of Henry Livingston, SRI International Workshop on Railroad Electrification, Fredericksburg, Virginia, April 19, 1978.

Without question, such direct federal funding would necessitate a major political decision; before these major sums are committed, Congress would have to examine the political and economic opportunity costs foregone as a result of such a decision. Considering that only a 1% reduction in petroleum imports would be realized, energy issues would probably be subordinate to other transportation issues.

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Appendix A

SRI RAILROAD INDUSTRY MODEL

Electrification of the major railroad freight routes will affect the profitability of U.S. railroads. The major capital expenditures required will, on the one hand, place the railroads in debt, even if those expenditures are partially financed by government loans or subsidies. On the other hand, the electric locomotive's greater efficiency may reduce costs and increase service quality, thereby increasing the share of the freight transportation market captured by the railroads, and allowing a greater share of the increased revenue to be used as badly needed new internal investment funds. The SRI Railroad Industry Model is designed to explore these effects. For example, the model can address the amounts of subsidies or loans that might be required from the federal government to support debt payment requirements resulting from electrification, the effect of retiring unprofitable low-density lines, and the effect of alternative scenarios of electrification of routes on railroad service quality, market share, freight rates, and financial health.

General Description

The SRI Railroad Industry Model incorporates a time-sequenced set of equations to represent the dynamic character of railroad operations. The model can simulate the financial and traffic operations of one railroad company, an aggregate of several companies, or the entire national industry. We have developed it to be simple, but, at the same time, have made it consistent with the sensitivity required to display the effects indicated above. Although all parts of the model are interconnected, to facilitate its description we divide it into the following major sectors:

- o Demand
- o Capital
- o Operations and cost
- o Rate determination
- o Finance.

The railroad system represented in the model consists of an arbitrary number of links. Each link is a single or double track segment or some mix of the two and has a specified length in miles. The traffic on each link is described in terms of gross ton-miles/year (gtm/y) and is called either electric or diesel. The diesel links found at the start of the scenario are converted one by one to electric links at specified times. Rolling stock is comprised of diesel and electric locomotives and boxcars, which can be used with either type of locomotive. The railroad system either owns or leases all equipment.

The model describes the freight demand for each link and for (1) high-value commodities (e.g. manufactured goods), (2) medium-value commodities (e.g. piggyback freight), and (3) low-value or bulk commodities (e.g., coal, grain, ores). Demand is separated into commodity types to illustrate how changes in the rate and quality of service (represented by transit time) affect freight demand for each commodity.

The operating costs described are calculated from the freight traffic and from the inventory of equipment, road, and structures. Freight rates are set by taking into consideration operating costs and past ICC regulatory behavior. Finally, the model incorporates four sources of financial capital for new equipment and for road and structures—equipment debt (e.g. equipment trusts and conditional sales contracts), funded debt (e.g. bonds), common and preferred stocks, and federal loans or subsidies.

Model Structure and Major Assumptions

Figure A-1 depicts the structure of the SRI Railroad Industry Model. The five sectors are outlined by dashed lines. Four types of major variables are defined:

- o Input quantities, some of which change with time, are shown as double circles.
- o Quantities that are calculated within the model and that represent current conditions are shown as single circles.
- o Quantities that are accumulated rather than recalculated each time period are shown as rectangles.
- o Quantities that are calculated from other parameters with a specified time delay are shown as squares.

To simplify the diagram, the variables that the model may disaggregate into further components are shown as a single entity. The type of disaggregation of each variable is shown by an asterisk if it is disaggregated by link, a "c" if by commodity, and an "r" if by rolling stock. If a variable is multiplied by the inflation index, it is shown with an "i." The lines between the variables indicate the flow of information. Thus, the value of each variable is calculated from the values of the variables whose arrows enter it. For example, the variable labeled "diesel and electric traffic" for each link and commodity is calculated from the "latent demand" and the "market share" for that link and commodity.

Demand Sector

The upper portion of Figure A-1 shows the structure of the demand sector and introduces the concept of "latent demand". Latent demand is the sum of two

FIGURE A-1. SRI RAILROAD INDUSTRY MODEL

component demands, one for which the railroads compete in the long run with other freight transport modes, and the other, a noncompetitive demand. The sum of these two demand components is the asymptotic demand that the railroads could conceivably satisfy if their rates were quite low and the quality of the service they provide quite high. For each of the 14 links and 3 commodity types, Table A-1 presents estimates of the latent demand and the competitive fraction; these values were used in the model as starting values for 1975. Traffic, which is set to be the noncompetitive demand plus 50% of the competitive demand, is shown in the last three columns of Table A-1. Except for the total freight traffic on each of the links, the data shown in Table A-1 are subjective; they were estimated from data on the types of commodities carried on each route by railroads and other competing modes of freight transportation (where they existed). Latent demand is assumed to grow at an annual rate of 1% on all links and for all commodities, except for low-value commodities on the Burlington Northern link (6). This link traffic is a primary route for the transportation of coal from the West to eastern and midwestern markets. The traffic on that link is assumed to grow at an annual rate of 25% in 1975, dropping asymptotically to 5% just before the year 2000. For the nonelectrified case, the traffic on that link was further limited to 120×10^9 gtm/y, a figure that is consistent with maximum diesel traffic on three tracks. In the electrified cases, the link 6 traffic limit was raised to 180×10^9 gtm/y, consistent with the greater traffic that electrified operations could accommodate.

Each link's commodity traffic is comprised of noncompetitive demand and the link's market share of the competitive demand for that commodity. The market share is assumed to be 50% at the start of electrification and to change as a result of changes in freight rates and quality of service. The change in market share is calculated from elasticity coefficients for each commodity. These coefficients (see Table A-2) were derived from data generated by the FRA's "National Intermodal Network Feasibility Study" (1976).

Table A-1
DEMAND INPUTS

Link	Company	Terminals	1975 Latent Demand (10 ⁹ gtm) Commodity Value			Fraction Compet- itive	1975 Traffic (10 ⁹ gtm) Commodity Value		
			Low	Med.	High		Low	Med.	High
1	SP	Colton-El Paso	15.0	14.1	0.9	0	15.0	14.1	0.9
2	ATSF	Barstow-Clovis	22.2	15.5	1.1	0	22.2	15.5	1.1
3	UP	Council Bluffs-Salt Lake	25.4	13.3	1.0	0.25	22.2	11.6	0.9
4	C&NW	Chicago-Omaha	17.7	9.3	0.8	0.50	13.3	7.0	0.6
5	CR	Chicago-Albany	54.2	18.7	4.7	0.43	42.7	14.7	3.7
6	BN	Lincoln-Alliance	6.9	0.4	0.0	0.50	5.2	0.3	0.0
7	SP	Ogden-Roseville	14.2	13.3	0.8	0.25	12.4	11.6	0.7
8	ATSF	Clovis-Chicago	28.0	19.6	1.4	0.22	24.9	17.4	1.2
9	N&W	Bellevue-Roanoke	19.0	4.6	1.1	0.22	16.9	4.1	1.0
10	Chessie	Chicago-Pittsburgh	21.9	5.8	1.5	0.83	12.8	3.4	0.9
11	Chessie	Pittsburgh-Washington, D.C.	15.4	4.1	1.0	0.77	9.5	2.5	0.6
12	Chessie/SOU	Toledo-Atlanta	18.2	4.9	1.0	0.23	16.1	4.3	0.9
13	NW	Roanoke-Norfolk	9.2	1.9	0.3	0.22	8.2	1.7	0.3
14	ICG	Chicago-Memphis	12.0	10.2	1.0	0.14	11.2	9.5	0.9

Table A-2

ELASTICITY COEFFECIENTS OF FREIGHT DEMAND

	Commodity Value		
	<u>Low</u>	<u>Medium</u>	<u>High</u>
Fractional change in demand per:			
Unit fractional change in freight rate	0.129	0.133	0.137
1-hour reduction in transit time	0.028	0.032	0.036

Change in freight rate is measured against the rate prevailing in 1974. The reduction in transit time resulting from electrification is assumed to be 1 hour per 100 miles of electrified route for flat terrain and 2 hours per 100 miles for mountainous terrain. This is based on a 10% decrease in transit time due to electification (20% for mountainous terrain) and an average of 10 miles per hour for a typical diesel freight schedule. This seemingly low speed is reasonable, given that most transit time is spent in yards, stations, and loading facilities, and not en route. The effect of the market share calculated is delayed for 10 years to represent the time necessary for rates and quality of service to change sufficiently for a shift in demand to occur.

Capital Sector

The cumulative capital investment in the model consists of (1) six types of rolling stock (diesel locomotives, electric locomotives, and boxcars, with each either owned or leased) itemized by number of units, (2) road and structure, and (3) total rolling stock investment in dollars. Each type of capital is increased by new purchases or new investment, and decreased by retirement and depreciation. The miles of double and single track, the nature of the grade (whether mountainous or flat), and the starting date of electrified operations are shown for each link in Table A-3.

Requirements for new rolling stock are generated by extrapolating each commodity-link demand one year in the future, corresponding to the time required between placing an order and delivery of a new locomotive or freight car. That demand is translated into rolling stock requirements by using horsepower-to-weight ratios (HPWR) and locomotive horsepower capacities. The HPWR and their relationship to locomotive requirements were obtained from the FRA, which derived them from detailed runs of a freight operations model. The equations are:

$$\text{Number of Diesel Locomotives} = 3.4 \times \text{HPWR} + 0.51$$

$$\text{Number of Electric Locomotives} = 0.96 \times \text{HPWR} + 1.3$$

Table A-3

LINK DATA

Link*	Route Miles		Horsepower/Weight Ratio for Low Value Commodities ⁺ (hp/gt)	Electrified Operations Date	Terrain [#]
	Single	Double			
1	730	20	1.1	1985	M
2	240	728	1.1	1986	M
3	0	992	1.2	1987	M
4	59	404	1.2	1988	F
5	0	825	1.2	1989	F
6	366	0	2.0	1990	M
7	491	214	1.2	1991	M
8	441	644	1.2	1992	F
9	67	481	1.75	1993	M
10	55	432	1.0	1994	F
11	0	318	1.0	1995	M
12	503	213	1.0	1996	F
13	0	255	1.75	1997	M
14	50	489	1.0	1998	F
TOTAL	3002	6015			

* See Table A-1 for definition of link number.

+ Horsepower/weight ratios for medium- and high-value commodities are twice and three times those for the low-value commodities, respectively.

M=mountainous; F=flat.

These equations assume 3000 hp per diesel locomotive and 5100 hp for electrics. The model includes an additional 1.25 diesel locomotives for each 10^9 gtm to provide for yard use and way trains. The number of locomotives required to meet future demand is first compared with the inventory and adjusted for retirements and previous orders; then an order is placed for the additional locomotives needed. When an order for electric locomotives for a newly electrified link is placed, the diesels previously used on that link become surplus stock. Those that are not required to meet the anticipated growth on other diesel links are sold at one-fourth of the current cost of a new locomotive. The proceeds from these sales are used to help pay for the new electric locomotives.

Freight car requirements are calculated at 0.66 per 10^9 gtm, the ratio existing in 1974 for the combined total of all Class I line-haul railroads (ICC, 1946-1975). For the Santa Fe model runs, 0.51 per 10^9 gtm was used, the Santa Fe ratio for 1974.* Of the locomotives 22% (8%) and of the freight cars 20% (10%) are assumed to be leased from nonrailroad companies; these were the proportions in 1974. Unit costs for new rolling stock in 1974 dollars were assumed to be \$350 million per diesel locomotive, \$610 million per electric locomotive, and \$22,000 per freight car. We derived diesel locomotive and freight car costs from the ICC accounts for 1974, and to estimate the electric locomotive costs we used the relative locomotive cost factor given in an Arthur D. Little, Inc. (ADL) study (Schwarm, 1976). The lifetimes assumed for rolling stock are 22 years for diesels, 30 years for electrics, and 25 years for freight cars.

The conversion costs (in 1976 dollars) for converting track to electrified operation are based on the following figures derived from ADL study:

*Note: In subsequent discussion, data for the Santa Fe are shown after the national figures in parentheses where different.

- o \$ 86,000 per track mile for the catenary
- o \$442,000 per electric substation located every 40 route miles along a single-track route
- o \$627,000 per substation located every 40 miles along a double track route
- o \$ 62,000 per route mile for communications and signaling modifications.

Table A-4 shows civil construction costs, for example, the cost of bridges, tunnels, expanded rights-of-way, and improved crossing facilities and stations.

Table A-4

CIVIL CONSTRUCTION COSTS FOR ELECTRIFICATION
(Thousands of 1974 Dollars)

<u>Link*</u>	<u>Route Miles</u>	<u>Cost</u>	<u>Link</u>	<u>Route Miles</u>	<u>Cost</u>
1	750	4,780	8	1,085	6,510
2	968	5,808	9	548	8,132
3	992	5,952	10	464	24,350
4	463	2,778	11	318	15,900
5	825	41,250	12	716	4,296
6	366	2,196	13	255	1,530
7	705	6,134	14	539	3,234

*See Table for A-1 for definition of link numbers

The cost of new rolling stock is added to investment at the time the stock is ordered. Similarly, track conversion costs are added to road and structure investment 1 year before operations begin. Road and structure investment is comprised of (1) a nondepreciable component for which retirement accounting is used, and (2) a depreciable component. The nondepreciable component consists of the track, roadbed, and rights-of-way; the depreciable component includes buildings and tools and equipment. The depreciable component is assumed to have an average book life of 20 years. In accord with 1974 ICC accounts, facilities rents are calculated as 0.3% (0.25%) of a total road and structure investment.

Operating Cost Sector

Total operating expense is divided into components, with a scaling variable assigned to each; the value of the scaling factor is derived from the ICC accounts for 1974 (ICC 1946-1975). These components, variables, and factors are:

1. Route maintenance costs = $\$0.61/10^3 \text{ gtm}$ (\$0.36)
2. Track maintenance costs = $\$0.49/10^3 \text{ gtm}$ (\$0.30)
3. Crew labor costs = \$64.80 (\$54.89) per train per hour (per train-hour). Because there were 87,810 gtm/train-hour (111,700) in 1974, crew costs are equivalent to $\$0.74/10^3 \text{ gtm}$, (\$0.49).
4. Locomotive maintenance costs = \$0.47/locomotive-mile (\$0.22) for diesels and \$0.201/locomotive-mile (\$0.095) for electrics. An average 163 (213) locomotive miles/day for 365 days/year is used. We obtained the ratio of electric-to-diesel locomotive maintenance costs from the ADL study.

5. Equipment rents = \$17,500/year for existing diesels
\$73,500/year for new diesels
\$134,000/year for new electrics
\$3,260/year for existing freight cars
\$4,770/year for new freight cars.

Leasing costs for existing rolling stock are derived from the ICC accounts for 1974. For new rolling stock, leasing costs are calculated by amortizing the new equipment costs over the lifetime assuming a required 15% DCF rate of return to the leasing company.

6. Diesel fuel costs = 0.26/gal in 1975, \$0.44/gal in 2000, and \$0.47/gal in 2025, in 1974 dollars. These prices were obtained from an EPRI study that used SRI's energy model to forecast energy use to 2020 (SRI, 1977). The average diesel fuel use rate, 197 gal/10³gtm, equals that for Class I railroads in 1974.
7. Table A-5 shows electricity costs. These costs were derived from the same SRI Energy Model runs as the diesel fuel costs, but differ for each census region. The electricity conversion rate was derived by using the following assumptions:
- o 1.78 gal/10³gtm = 1974 diesel use for freight service (not including yard switching and work trains)
 - o 136,000 Btu/gal = typical diesel energy content
 - o 30% conversion efficiency indicated in the ADL study.

Table A-5

COST OF ELECTRICITY FOR EACH LINK
(Cents/kWh)

	<u>Link</u>	<u>1975</u>	<u>1985</u>	<u>2000</u>	<u>2025</u>
1	Colton-El Paso	1.39	2.11	1.99	1.87
2	Barstow-Clovis	1.39	2.11	1.99	1.87
3	Council Bluff-Salt Lake	1.70	2.54	2.38	2.22
4	Chicago-Omaha	2.00	2.89	2.71	2.52
5	Chicago-Albany	2.32	2.79	2.61	2.42
6	Lincoln-Alliance	2.00	2.97	2.77	2.57
7	Ogden-Roseville	1.39	2.11	1.99	1.87
8	Clovis-Chicago	2.00	2.97	2.77	2.57
9	Bellevue-Roanoke	2.10	2.89	2.72	2.54
10	Chicago-Pittsburgh	1.99	2.82	2.65	2.48
11	Pittsburgh-Washington DC	2.43	2.84	2.66	2.48
12	Toledo-Atlanta	1.79	2.80	2.63	2.45
13	Roanoke-Norfolk	2.24	2.97	2.79	2.61
14	Chicago-Memphis	1.99	2.82	2.65	2.48

The product of these terms yields 72.6 Btu/gtm required at the rail. Because electric locomotives use no energy while stopped and no fuel is spilled or stolen, the average Btu at the rail required can be reduced by 30% to 50.8 Btu/gtm. To convert this figure to kilowatt-hours at the power line, we used ADL's factor of 1.25 Btu of electricity required per Btu at the rail (Schwarm, 1976). When this factor is used to convert to kilowatt-hours, we get 18.6 kWh/10³ gtm.

The model incorporates effects of inflation by multiplying each inflatable cost by an inflation factor. The variables inflated to current dollars in this way are shown in Figure A-1 by an "i" appearing in the symbol. All operating costs and costs of new equipment and facilities are inflated to current dollars. We employed the inflation forecast in the consumer price index series from Social Security Administration annual report for 1977 (SSA, 1977), shown in Figure 7.

Rate Determination Sector

This sector represents the rate-setting behavior resulting from interactions of the ICC and the railroads. ICC allowance of rate changes cannot be described in terms of an allowed rate of return or other simple formula. Many factors are considered, including the desire to maintain a stable freight transport market, a stance that has led the ICC to deny rate reductions requested by the railroads for fear of disturbing the competitive market balance between the railroads and trucking industry. The ICC has also desired to maintain service on low-density routes without raising rates on those routes to pay their costs. As a result, higher rates are charged on high-value commodities on the high-density routes to subsidize the unprofitable low-density routes. To find a suitable representation of the historical results of rate-setting, we reviewed the financial summaries of the U.S. Class I railroads for 1960 through 1974. The operating ratio (i.e. the ratio between the total operating expenses and the total operating revenue) remained relatively constant during that period. The operating ratio has varied less than 2% from a value of 80% for all but 2 of the 15 years. Thus we chose 80% to approximate the effect of ICC rate setting.

The model combines the operating ratio with total operating expenses to calculate the allowed operating revenue. An "indicated" rate is first calculated by dividing the allowed revenue by the total traffic. A regulatory delay of 0.4 year is imposed on changes in the rate to represent the administrative delays encountered by the railroads in applications for rate changes. The resulting freight rate is multiplied by the traffic to give total operating revenue. The freight rate is disaggregated into individual rates for the three commodities by assuming that the medium-value commodity rate is 1.4 times the low-value commodity rate and that the high-value rate is 2.3 times the low-value rate. (We derived these ratios by surveying typical rate differences between examples of each commodity type.)

Financial Sector

The right portion of Figure A-1 shows the finance sector. This sector keeps track of cash flow, profits, and sources of funds for new investment. Equipment debt finances new rolling stock investment as required. Surplus internal funds and new funded debt and equity finance new road and structure investment. A maximum debt-to-equity ratio can be used to determine the distribution of financing between funded debt and equity. This ratio was 0.59 (0.29) in 1974. The federal loan represents the amount of subsidy that the railroads will require, or alternatively, the degree to which they will go further into debt.

To obtain the net operating income, the model subtracts total operating expenses and income taxes from the total operating revenue. Income taxes are approximated as a linear function of the revenue. The equation coefficients were obtained by fitting a straight line to the data over the past 20 years. The income tax resulting is 10.6% (10.1%) of the revenue, minus \$27 (\$3.12) million. An investment tax credit for new investment in both equipment and facilities reduces the income tax according to the assumptions in Figure 8. Profit is next calculated by adding "other income" (i.e., net income from nonrailroad operations) to the net operating income and by subtracting interest payments. Because other income is large enough to provide a significant source of funds for the combined railroad system, it cannot be ignored. Its value as a fraction of revenue for the previous

20 years was obtained by fitting a linear equation to the data; this resulted in other income being set equal to 3.4% of total revenue, minus \$3.12 (\$6.5) million. The interest rate on new equipment debt, as well as new funded debt, is specified in Figure 7. The interest rate on federal loans was assumed to fall midway between the debt interest rate and the inflation rate. Internal funds for investment were next calculated as profit plus the depreciation (which is a noncash expense), minus the debt repayments, required additions to working capital, and dividends paid to the stockholders. The average equipment debt repayment period shown in the 1974 data was 8.85 years and that for funded debt was 15.64 years. Of the profits 54% (51%) were paid out as dividends.

The internal funds remaining for investment are applied to new facilities investment. If internal funds are inadequate for investment needs or if the cash surplus is inadequate even to cover debt repayments and dividends, the funds required are obtained by one of several assumed mechanisms: sale of common stock, new long-term debt, or government loans. Likewise, if the internal funds remaining for investment are more than enough to cover the investment financing required for that year, the surplus is used to repay previous federal loans. If no federal loans are outstanding, the surplus is used to buy new equipment. Finally, if a surplus still remains, it is used to pay off the equipment debt.

Implementation

The SRI Railroad Industry Model is programmed in FORTRAN IV and currently runs on the Burroughs 6700 computer. The program consists of approximately 600 statements, including all subroutines. Inputs are stored in a separate file for easy alteration and are read in at the beginning of the program. Outputs can be specified for any or all variables by means of a file of output specifications. Forms of output include lists of the values of each variable desired for each time increment specified, printer plots of variables vs. time, and graphics plots of the type that appears in the figures in the body of this report. To run the national scenario with 14 links for a demand scenario of 55 years costs less than \$5.00.