UNIT TRAIN TRANSPORTATION OF COAL

BY

JOHN ALAN FERGUSON

B.S., Eastern Illinois University, 1970
M.S., Eastern Illinois University, 1971

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Mechanical Engineering
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Final Report

The Coal Future: Economic and Technological Analysis of Initiatives and Innovations to Secure Fuel Supply Independence

by

Michael Rieber
Center for Advanced Computation
University of Illinois at Urbana-Champaign

and

Shao Lee Soo
James Stukel
College of Engineering
University of Illinois at Urbana-Champaign

Advisor
Jack Simon, Chief
Illinois State Geological Survey

Center for Advanced Computation
University of Illinois at Urbana-Champaign
Urbana, Illinois 61801

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1. INTRODUCTION

The trend in coal usage has been toward large consumers with smaller energy consumers relying on other more easily transported fuels. By far, the largest users of United States coal are the electric utility companies which, in 1970 alone, accounted for nearly 60 percent of the total demand [1a].* Other promising future large lot consumers may be coal gasification and liquefaction facilities. Coal is more suited to large consumers because of its relatively low mine mouth cost but high transportation cost. The transportation costs can be lowered significantly by dealing in large shipments. Currently, the most common method of moving coal is by rail, accounting for 67 percent, or 376 million tons, of the coal mined in 1969 [1b]. Other less significant modes include truck, barge, and slurry pipeline. While truck transportation can be economical for very short hauls, barge movement can serve only those consumers located on large rivers, lakes, or sea coasts. Slurry pipeline, although in use in several scattered locations throughout the United States, has not had the impact expected on coal transportation. It handles only a minor portion of coal traffic so far because it can be justified only over long distances due to large preparation and separation costs. Large consumers have cut conventional rail rates approximately 25 to 40 percent by utilizing unit trains to supply their needs [1c]. The following is a review of the operating and economic limits of the unit train. It provides a base for comparison with slurry and pneumatic pipelines.

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*Numbers in brackets refer to entries in REFERENCES.

The unit train is a single purpose train for hauling one commodity, coal in this case. It is composed of special purpose cars which haul continuously from mine to consumer. Its use dates back to 1957 when the Reserve Mining Company transported iron ore over a 50-mile private section of track to a processing plant at Silver Bay, Minnesota [2]. Utilization of the unit train for coal actually became prominent in the mid 1960's. Due to different definitions of the term unit train, it is difficult to say exactly what percentage of rail coal moves by this method; however, estimates vary from one-third to one-half of the total rail traffic in coal [1d]. Unless some other method shows promise, or unless consumer needs change, it is apparent that unit trains will become more and more in demand for hauling high volume coal shipments.

Unit coal trains really became refined in the late 1960's and have since improved even further. From the very beginning, its successful initiation has almost always depended on close cooperation between the mining company, the railroad, and the electric utility company. Typically, long term contracts (ten years or more) are made so that large capital investments for equipment can be justified, including the unit train itself and coal handling at both ends of the haul. Early operations were typified by railroad owned coal cars and locomotives, primarily because they already owned the equipment. When freight cars specifically suited to coal hauling and larger locomotives becane the rule rather than the exception, it became preferrable for the utility companies to own their own trains as part of their investment facilities and for protection from arbitrary dispatching; all train crews and most maintenance were provided by the railroad, however, Traditionally, the mining companies are more hesitant to assume unit train ownership, probably because they have less to gain from it than either the utility companies or the railroads. However, the associated contracts do provide a guaranteed outlet for the mine's coal and unit trains often lower the delivered cost of coal enough to encourage increased coal usage. For railroads, unit trains provide better equipment and plant utilization compared to other rail modes. For the coal burning utility companies, they lower fuel expenditures and establish a stable fuel supply [1c]. Lowering transport costs also increases the economically recoverable coal reserves so that mines may go deeper and increase recovery percentages thus effectively prolonging the time before mine closure. Higher recovery percentages are to the nation's advantage because once the mine is abandoned, often it was not reopened because reopening cost tends to overshadow the productivity via higher recovery techniques.

A unit train operation involves much more than merely the locomotive and freight cars to haul the coal. Successful operation is dependent upon concentrated usage of equipment so that the train spends as much time on the road as possible. To provide this condition, high rate loading and unloading facilities as well as great storage capability must be installed to supplement the train. Naturally, these improved coal handling facilities increase the delivered price of coal and must be included in the total economic and technological analysis of the unit train. Another factor which sometimes may be ignored in fixing unit train rates is the cost of building and maintaining the railroad. The trend in recent years has been to spend the absolute minimum on track maintenance and building new mileage (a result of the declining financial stability of the railroads and their diversification). It may be that upgrading unsatisfactory sections of track or actually building a new line could become economically feasible because of increased revenue of railroads through high degree of usage by unit trains. Some sections of track will allow speeds of only ten miles per hour [2] thus definitely hampering the efficiency of a unit train on a tight time schedule and reducing total utilization. Rail and tie replacements are presently at below average depreciation rates so that track conditions are declining or, at best, staying the same. A new effort must be made to develop either labor saving methods of track construction and maintenance or a totally new concept of track design.

In reviewing the operating and economic limits of the unit train, it becomes apparent that the railroads may have set rates without exactly relating to the underlying cost figures. In a 1963 report to the Secretary of Commerce, Science and Technology in the Railroad Industry [3], this was expressed as follows:

> "Pricing must depend upon knowledge of cost and components of cost. Until sufficient cost data are available, rates quoted by the railroads cannot accomplish their purpose of effective competition at a profitable price. The railroads have never instituted cost-finding procedures as a reference for pricing services. Although several different sets of books have been kept traditionally to meet the separate requirements of the ICC, the IRS, the various state reporting criteria and for responsibility accounting, none of the bookkeeping operations offers a basis for costing service."

Though this picture may be overly pessimistic for today's railroads in general, it probably comes very close to the situation with respect to unit train operations. However, such arbitrariness can be reduced through systematic quantification.

Probably the major catalyst to the formation of unit trains and the corresponding reduction of bulk railroad rates on these one-commodity trains was competition from coal slurry pipelines and on the East coast and the reduction of crude oil prices in the 1960's. Some large coal users had felt an urgent need to reduce transportation costs and had financed the successful construction of a coal slurry pipeline in Ohio [4a]. This pipeline posed a severe threat to the railroads as their largest volume commodity was coal and the slurry rates were far lower than their single car coal shipment rates. In a 1962 Department of the Interior publication, "Report to the Panel on Civilian Technology on Coal Slurry Pipelines [5], the impact of slurry pipelines was predicted as follows:

> "Since coal traffic is so important to the earnings of the railroads, especially in the East, we believe that they can ill afford to watch even a single new pipeline built without making every effort to minimize their own costs and adjust their own services in such a way as to meet the competition effectively, before the traffic is lost."

After a very short period of thought and re-evaluation of their techniques and profits, the railroads, in cooperation with the electric utilities and coal mines, instigated the unit train concept. Driven by the instinct for survival, the railroads undercut the delivered coal cost of slurry pipelines and put most of them out of business in a few years. The slurry line in Ohio was shut down and later converted to moving garbage from Cleveland. Presently, the only highly successful coal slurry line in the United States is the 273 mile Black Mesa line in the Southwest. One reason for its selection over unit train transportation was that otherwise a 150-mile section of track over rough terrain would have to have been constructed to serve the mine-to-powerplant route [6]. This project alone casts doubt as to whether unit train rates can compete with pipelines when no track is originally present.

2. LOADING AND UNLOADING FACILITIES

Successful initiation of a unit train operation is closely dependent upon the speed at which the coal can be loaded and unloaded. The more time the coal cars spend actually hauling to and from the mine and powerplant, the better, Before unit trains, railroad owned cars were delivered empty to the loading facility and loaded at leisure; that is, the car loading rate was probably near the mine production rate, thus minimizing the necessary storage but at a high demurrage cost. This technique allowed only very small annual usage of cars in terms of ton-miles moved. Hence, the cost of cars was given as the reason for a high rate charged by railroads. By increasing the usage of cars (many times by a factor of ten or more), the railroads could cut coal train rates drastically [7] to compete with, for instance, slurry pipelines. This cut in the delivered price of coal allowed the mines and power companies to bear the cost of high capacity coal handling equipment over a period of years.

The first prerequisite for a loading facility to handle the new unit trains is increased auxiliary track capacity. There are basically three ways of attaining this capacity: (1) a loop track, (2) a single siding, or (3) multiple sidings. The loop track is probably the most popular as it allows the train to remain coupled throughout loading and during turn around. Its main disadvantages are the large radius for turning and the space it requires. In many situations this space is readily available at the mine site. The minimum loop track or multiple siding lengths run over one mile in length, while single sidings are twice this length [8a]. Multiple sidings are sometimes used where only limited space is available. They are usually so short that the train must be broken into several sections upon arriving at the loading point. This increases loading time because of the extra car manipulation required. Any of these set-ups can also be used by the power companies for unloading.

In order to meet unit train demands, most mines must develop an expanded storage system to enable them to handle the rapid loading rates. In 1971 there were only 25 operating mines in the United States that were larger than 2 million tons per year, and only three of these mines exceeded 5 million tons per year [9]. If we assume a typical large mine capacity of 2.5 million tons per year, then, based on a 250-day working year, mine production amounts to 10,000 tons per working day. This is a typical tonnage for a single unit train; thus, at least one day's mine capacity must be stored to load a unit train (assuming negligible loading time). Actually, some mines carry as much as 50,000 tons or more live storage to meet varied demands [8a]. Many mines are feeding their entire output to one power plant via unit trains. Maintaining storage capacity for several unit train loads minimizes the change of holding up a train due to mechanical failure or worker stoppage in the mine. Utilities normally maintain a 60-day storage as a hedge against strikes at the mine or the railroad.

Storage of either washed or raw coal can be maintained in the form of a ground storage pile or the more recent form of closed cylindrical silos. Enclosed silos are usually beneficial in avoiding water and air pollution difficulties associated with open storage [8a]. The sharply sloped inner walls of the silo provide another advantage, that of almost 100 percent live storage or complete coal recovery. Typically, open stacks are far from 100 percent live storage without help from bulldozers or endloaders. Unless the coal in dead storage is compacted sufficiently, there may be a significant explosion hazard when it remains for a period of months.

Silos are constructed with relatively small base areas to simplify reclaim operations. Hence, there can be a savings in the number of coal feed ports and the number of mechanical coal feeders which supply the loadout conveyor. Naturally, there is a trade-off when the height of the silor is increased. Surface-to-volume ratio, as well as construction costs, increase significantly for an extremely tall silo. Even before these two factors, there is another more important one: Conveyors loading the silo must feed into the top of it; extra height requires a longer conveyor. The maximum possible inclination with a belt type conveyor is about 18 degrees; thus, doubling the silo height necessitates a doubling of conveyor length if it is already at an 18-degree inclination [10a]. Energy requirements to raise the coal to the height must also be considered. Another constraint on the size of coal storage silos is presently available designs. A special order silo might be feasible but not economical due to increased engineering costs.

Storage capacity for nine representative mines varied from 367 to 800 percent of the daily unit train capacity in a 1970 Bureau of Mines study [8a]. The larger figures were associated with open stock piles. Ground storage piles are usually stacked in one of four shapes: (1) windrow, (2) kidney, (3) spread, and (4) conical. Each shape requires different equipment. The windrow pile is shaped by a traveling stacker; kidney shaped piles, by a pivoted and hinged belt boom; the spread pile, by scrapers, trucks, and bulldozers; and the conical pile, by a fixed stacking belt and tube [8a]. Typically, conical piles are about 100 feet in height and hold about 40,000 tons of coal. Conical piles much higher than this become impractical because of the higher percentage of dead storage added. The normal angle of repose of coal is near 40 degrees. Most operations are set up to recover about one-third of the pile without using a bulldozer to push the dead storage into the reclaim ports [10a]. This dead storage must be rotated at least every six weeks during periods of high moisture and every 10 weeks during the winter months to prevent spontaneous combustion problems [8b]. Steel stacker-dust tubes are employed to eliminate coal dust which is instrumental in combustion. Coal fed to the stock pile enters this steel tube at the top and the dust falls out before the coal exits through ports in the side of the tube. Another factor that may contribute to explosions is the release of occluded methane by some coals. This condition can arise in the reclaim tunnels under stockpiles where levels of methane have been known to reach 2 percent even with considerable ventilation [10b]. Hence, care must be exercised to avoid sources of ignition (e.g., electric lights or exposed wiring).

Belt-type conveyors are used both to move the coal from the preparation plant to storage as well as to move it from storage out to the track tiple. The size of conveyors running from the preparation plant or mine is rather small in comparison to the loadout conveyors, generally from 36 to 48 inches in width with capacities of from 400 to 1,500 tons per hour (tph) [8c]. Size is determined by mine capacity, hours of preparation plant operation, and storage capabilities in the preparation plant. Assuming a 16-hour work day, a 6-day work week, no storage capacity within the preparation plant, a 2 million ton annual production for unit trains, and adequate storage capacity, a 400-tph conveyor belt is adequate. An upper limit based on a very large mine (5 million tons annually), working a relatively short day of 10 hours, and a 5-day work week requires a conveyor of 1,920 tph capacity; probably the size of the largest storage conveyor in use.

Loadout conveyors are naturally larger than storage conveyors because they must load a unit train as quickly as the loading facilities allow. In the 1970 Bureau of Mines study [8c], loadout conveyor sizes were either 60 or 72 inches in width and had capacities of 2,500 to 4,000 tph. A capacity of 3,000 tph is equivalent to 50 tons per minute which is sufficient to load a 100-ton coal car in two minutes or a 10,000-ton train in three hours and 20 minutes. Many loading rates are higher than this as evidenced by a 1972 advertisement for the Lively Manufacturing and Equipment Company. The advertisement mentioned an ultra-modern, high-speed railroad loading system built for the Decker Coal Company in Montana with a 5,500-tph loadout capability [11].

Unloading facilities utilize much of the same equipment used in loading facilities. Provisions for unloading unit train cars are substituted for car loading provisions. Unloading facilities generally have much more storage capacity than is normally maintained at the mine loading site. This is necessary because the electric utilities must maintain an uninterrupted supply of coal in spite of strikes or other supply difficulties. There has been a trend toward larger capacity power plants which must maintain a 2- to 3-month coal supply. An operation such as Detroit Edison's Monroe Power Plant, which can burn 8 million tons of coal annually, maintains a two-month supply or 1.3

million tons of coal storage [12].

Coal storage requirements of this size can be economically provided only by open storage piles. Generally, the storage pile is a flat "spread pile" type which can be compacted by bulldozers to prevent spontaneous combustion of the dust. It remains relatively intact with daily unit train unloadings supplying the plant's daily needs directly. Usually an intermediate live storage pile is also maintained to smooth out daily supply fluctuations and provide a steady flow to the steam generators.

Unloading time for unit trains is considerably less than the corresponding loading time. An extremely high-speed unloading system, fed by the Black Mesa and Lake Powell Railroad in Arizona, is capable of unloading a 10,000-ton capacity train in 20 minutes. The 83-car train moves through a 360-foot long unloading shed where six 4-door bottom dump cars are unloaded simultaneously [13]. Installations using the lighter gondola cars and rotary car dumps generally are not as efficient; however, overall they can be less expensive to operate because of fast unloading and light empty trains.

3. UNIT TRAIN OPERATION

Initially, unit trains were made up from existing equipment. Now, it has become economical to design and construct locomotives as well as coal cars specifically for the purpose of hauling high volume shipments. Typically, cargo capacities are based on 100-ton capacity cars instead of older cars scarcely two-thirds that size. Also, train size, in terms of length, has increased, putting further demands on locomotive power. The freight train operation, in general, has begun to rely on higher horsepower locomotives. Single units of 3,500 to 4,000 horsepower are not uncommon. These units can save the railroad companies a great deal in maintenance costs as a larger locomotive takes a proportionately smaller cost of maintenance per horsepower than does a smaller unit. When a large locomotive goes to the shop for repairs or routine maintenance, many operations are the same regardless of horsepower (especially in the running gear). Higher horsepower single units cuts down on the space and often on the weight per horsepower of the locomotive thereby allowing a larger amount of cargo to be hauled.

Many railroads are now leaning toward more horsepower per net ton of cargo thereby allowing higher speeds, especially over lines with many steep grades. Common railroad grades range up to approximately 3 percent on main lines with a few stretches up to about 4 percent. There are some spur tracks, sidings, and secondary tracks with short sections of grade of up to 5 percent. However, the majority of significant grades for mainline service run from 0.7 to 3 percent [14]. Approximate power requirements for various speeds (above 40 mph) and grades (below 2 percent) are shown in Fig. 1 (note that to attain a speed of 40 mph up a 1 percent grade, or approximately 20 mph up a 2 percent grade, requires 2.0 kw/ton gross weight or 2.68 horsepower per ton gross weight at the rail). Typical efficiency factors suggested by S. L. Soo include 80 percent electrical efficiency and 90 percent drive efficiency for diesel-electric locomotives, yielding 72 percent overall [16]. W. W. Hay suggests an overall efficiency of 81 to 82 percent [17]. Using a 77 percent total efficiency for calculation purposes, a value of 3.48 hp (engine)/ton gross weight is obtained. A train of 15,000 ton gross weight would require more than seventeen 3,000-hp locomotives to satisfy this power/weight requirement. This ratio is considerably higher than those presently employed.

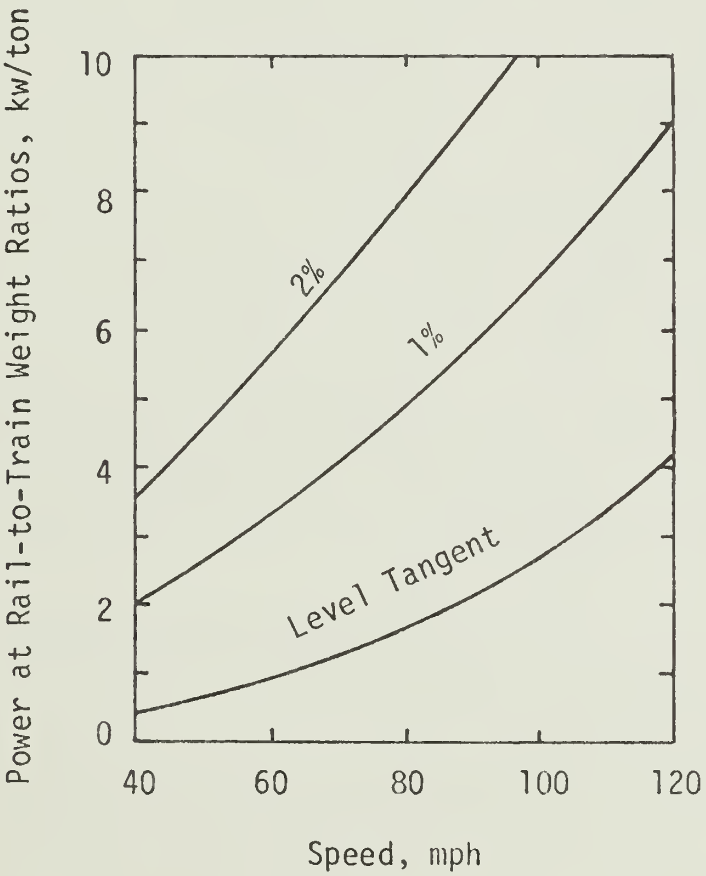

Figure 1 Power at the Rail/Train Weight Ratios Required at Speeds and/or Grades Shown [15]

A practical comparison with actual power/weight ratios over a fairly steep grade is worth noting. A recent Canadian Pacific 100-car unit train running in southwestern Canada crosses the Rocky Mountains with grades as much as 2.2 percent with eleven 3,000-hp locomotives [18]. Among the highest horsepower single locomotive units are those built by MLW-Worthington with 4,000 horsepower and 398,000 pounds total weight [19]. The power/weight ratio of these units is just over 20 horsepower per ton of locomotive weight. Based on this figure, the eleven 3,000-hp units weigh just over 1,650 tons. If 100 coal cars each hold 105 tons and weigh 25 tons when empty, then total train weight would be 14,650 tons, neglecting caboose weight. In other words, the net or cargo weight is 72 percent of the gross train weight. This is an engine power/train weight ratio of 2.25 horsepower per ton or 3.14 horsepower per ton cargo, compared to the previously cited value of 3.48 engine horsepower per ton train weight for a one percent grade at 40 mph. However, H. L. Smith, Chief Engineer of the Electro-Motive Division of General Motors Corporation, estimated that a diesel locomotive with 3 horsepower (engine) per ton cargo can, on a level track, attain speeds of up to 71 mph [4b]. Smith estimated that heavy duty highway trucks require 7 to 8 horsepower per ton of cargo.

Curve resistance and grade resistance can frequently put a horsepower or speed restriction on a unit train. Rail horsepower and rail resistance are related by the following formula:

$$\text{horsepower} = \frac{\text{resistance (lbs)} \cdot \text{speed (mph)}}{375}$$

Using figures from W. W. Hay [20] of 20 lbs per percent of gradient as the resistance per ton and 0.8 lb per ton per degree of curve as the curve resistance, the equivalent curve resistance in terms of grade can be calculated. This yields a figure of 0.04 percent gradient equivalent per degree of curvature or 25 degrees of curvature adds the same resistance as a 1 percent grade.

The gross weight of unit trains continues to rise; this is a result of two factors. First, the capacities of the coal hopper and gondola cars are being increased to provide better efficiency. Empty or lightly loaded trains have higher resistance per ton of weight because train resistance forces due to mechanical movements and friction change very little for wide variations in weight per wheel. Also, air or wind resistances are a much higher proportion of the resistance per unit of weight on empty or lightly loaded trains. At 40 mph, an empty car (30 tons gross weight) has a resistance of 9 lbs/ton while a loaded car (125 tons gross weight) has a resistance of only 5.2 lbs/ton [14]. Second, unit trains are growing in length with most in the 100 to 150 car range. The usual length limitations are: regulations designed to prevent blocking of urban crossings, the size of auxiliary track at loading and unloading points, as well as draw bar pulls. Frequently, the last restriction can be avoided by spacing the locomotives throughout the train.

According to J. F. Stover [4b], a typical freight train can produce close to 200 ton-miles of freight movement per gallon of diesel fuel while the average highway truck reaches only one-third that efficiency. Unit trains, because of their simplicity of traffic pattern, can be more efficient than the average of freight trains. R. A. Rice, Professor of Transportation at Carnegie-Mellon University, states that railroad trains, including passenger trains, have a gross efficiency of 550 ton-miles per gallon of diesel fuel [21]. Based on the earlier example where cargo weight was 72 percent of gross weight and assuming the train spends 50 percent of the time on the tracks empty, net ton-mileage per gallon should be 36 percent of gross ton-mileage per gallon. Obviously, there are many factors affecting this percentage which include the following: grades negotiated, locomotive horsepower/weight ratio, and freight car tare weight/maximum gross weight ratio. 1971 Transportation Statistics [22] show that Class I railroads spent $363 million on freight diesel fuel and moved 750 billion ton-miles of freight, yielding 0.484¢/ton-mile. The price paid for fuel averaged 10.88¢ per gallon [23]. Dividing the fuel cost per gallon by fuel cost per ton-mile yields 225 ton-miles per gallon which is fairly consistent with Stover's figure.

4. RAILROAD SUITABILITY

Possibly the one situation that needs the most improvement if long distance unit coal trains are to fluorish is the condition of railroad tracks and roadbeds. At present, the state of track maintenance is only fair. The railroads are failing to uphold present track conditions in most areas. In addition, the railroads are seeking to abandon many dilapidated and little-used lines (less than 34 cars per year) to reduce their outlay for track maintenance. Decreasing the amount of suitable rail mileage can only worsen the railroad position with respect to other forms of transportation. This condition may not appear to have an immediate effect on the cost per ton-mile; however, it may lead to longer distances between supply and consumption points. One of the disadvantages of existing rail transportation is that railroads cannot follow a "crow-fly" route along supply lines. Many newly constructed pipelines come very close to a "crow-fly" route, especially in the sparcely populated western part of the United States. Over short hauls, it may become economical to build new sections of trackage to approach a direct route.

The 1968 rate of tie replacement was only 48 years and the rate of rail replacement was 131 years [24a]. According to current estimates, new rails can reasonably be expected to last an average of 60 years, including subsequent reuse in secondary lines and tie replacement on an average of every 35 years [24b]. Hence, it becomes apparent that at this rate of tie and rail renewal, the railroads will be badly crippled by the end of the 20th century. On March 30, 1971, George A. Smathers of America's Sound Transportation Review Organization stated that $5.8 billion should go into an accelerated program of replacing rails and ties.

This would correspond to a three-fold increase in rail replacement rates for new rail and a 50 percent increase over recent replacement averages. He stressed that another $6 billion (nearly double recent spending levels) is needed for investment in improvements to freight yards, communication networks, terminals, and other facilities [25]. Railroads must increase track maintenance expenditures or abandon some of their secondary lines to retain the condition of their tracks. This second alternative seems to be the one preferred by the railroads. However, it has met strong opposition from other special interest groups. It is to the benefit of the coal interests to have most lines retained and to have increased maintenance which, at this point, will probably require government support. Thus far the maintenance to the roadbed itself and the supporting ballast has not been considered; however, with the exception of upper ballast,these wear out at a much slower rate and are less of a factor. It will be demonstrated later that upon construction of a new right-of-way,tie and rail costs are small compared to other roadbed costs (including earth moving, etc.).

As reported in the 1971 Annual Report of Transportation Statistics [22], Class I railroads spent $1.72 billion on maintenance of way and associated structures while moving 750 billion net ton-miles of freight; in other words, they spent 0.229¢/net ton-mile. In 1973, costs for maintenance of way and structures rose to $2.04 billion; this was still less than the $2.54 billion spent for maintenance of equipment and $5.90 billion spent for transportation costs in general. These three major expenditures account for 91 percent of railroad expenses [26]. In the case of unit coal trains with rates in the neighborhood of 0.5 to 0.9¢/net ton-mile, it might seem that the 1971 figure of 0.229¢/net ton mile for way and structure maintenance is out of proportion. Unit train operations do not necessarily have the same percentage split between the three previously mentioned major expenditures. Due to the high mileages logged on coal cars and locomotives in coal unit train service, the maintenance of equipment per ton-mile figure is lower. Transportation costs per ton-mile, including labor and fuel, are also much lower due to the inherent efficiency advantages of unit trains. The higher carload sizes (many approaching 150 tons gross) may lead to premature track wear unless these cars are made with three (rather than the normal two) trucks or with the larger wheel sizes now available. One might imagine that the maintenance of way and structures figure per ton-mile might possibly approach either of the other two expenses under these special conditions.

Rail capacity is a function of different factors depending on whether it is a single track or a double track. Single track capacity is largely a function of the number of sidings available enabling trains approaching each other to pass without delay. On a double track, track capacity is theoretically limited only by maximum train braking distances and minimum spacing for signaling. Double track railroads are typically broken into signal blocks. The presence of a train in a block prevents other trains from entering the block; one train may activate signals regulating the speed of trains two to four blocks in the rear [27].

At best, coefficient of friction values for steel wheel-on-steel rail are in the range of 0.15 to 0.3 depending upon track conditions, etc., [28a]. A train traveling at 50 mph, with maximum available coefficient of friction of 0.1 and ideal braking, decelerating at a uniform rate, would require 835 feet in which to stop. This allows for no reaction time of the engineer or brake system and probably does not provide an adequate safety margin to prevent locking-up of the wheels and hence damaging them by flatspotting. Also, trains are often operating with less than ideal brake systems; that is, brake piston travels may be at their greatest extent, the train may be loaded to capacity, the brake blocks may be worn, and the maximum permitted number of brake cylinders may be cut out [28b]. Deceleration rates must be blended slowly during the onset and finish of braking to avoid jerking which can cause dislocation and damage to freight. For practicality, braking distances of one mile probably provide a reasonable safety margin. In actuality, the signal spacing or block size is probably more limiting than actual braking per- [illegible] with signal block size at least as long as the longest trains [illegible]

5. ILLINOIS UNIT TRAIN MODEL

A model of Illinois unit train coal transportation is formulated to evaluate the economics of a specialized railroad line supplying electric utilities or future gasification facilities in Chicago and vicinity with Illinois coal (largely from southwestern Illinois). It is also used to formulate and demonstrate a computer model of a general unit train system. The consumption point is Joliet, Illinois, since it lies at the head of several rail lines, is located on the Illinois River (providing a water supply), and is near enough to Chicago to supply electrical needs. A supply map of producing coal areas from the Keystone Coal Industry Manual is the basis for route selection and length (Fig. 2) [29]. In order to serve the supply area, 600 miles of double track is required, 350 miles of main line, and 250 miles of branch line. A round trip distance of 500 miles is assumed. If this figure is incorrect, a larger distance may be more appropriate to account for the high percentage of coal from southern Illinois. A double track is selected because it has a much higher track capacity limit than a single track which must include multiple sidings for flexibility. Also, a figure for projected building costs is available for double track on a large scale.

The unit trains are assumed to be in continuous operation as are the loading and unloading facilities. Train crews remain with the train during loading and unloading as well as during maintenance operations. In some operations the train is moved by car positioners for loading or unloading; however, many operations still employ the locomotive units themselves to position the cars and hence require a crew. The Illinois model is described by data shown in Tables 1, 2, and 3 followed by pertinent assumptions, calculations, and further comments.

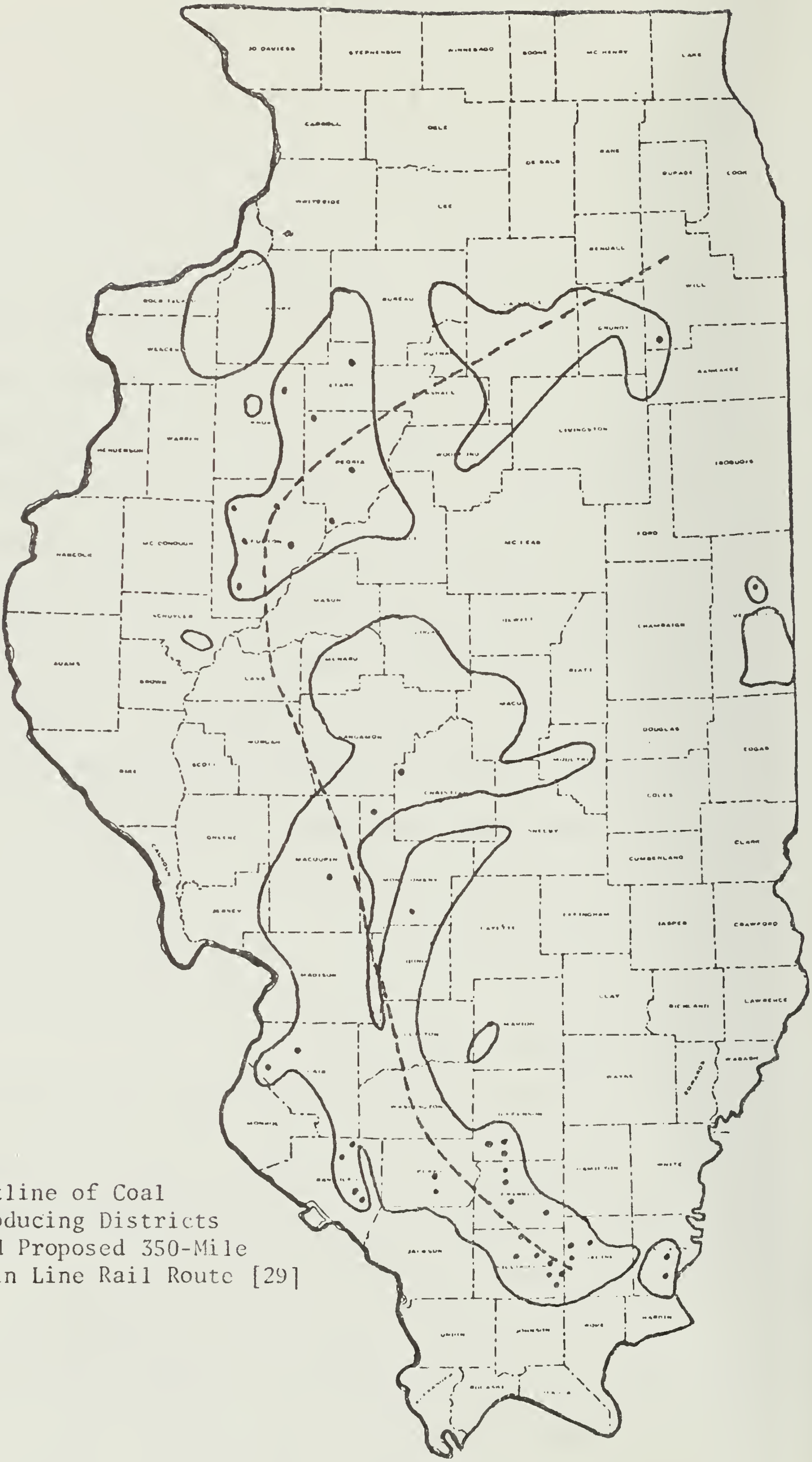

Figure 2 Outline of Coal Producing Districts and Proposed 350-Mile Main Line Rail Route [29]

Table 1 Illinois Coal Unit Train System Specifications

	English	Metric
Car Capacity, net short or metric tons	103.5	93.89
Train Capacity @ 100 Cars per Train, net short or metric tons	1.035×10^4	9.389×10^3
Number of Unit Trains Active	15	
Number of Cars Required (2)	1,650	
Average Round Trip Distance, miles or kilometers	500	805
Average Train Speed (Loaded), mph or km/hr	50	80.5
Average Train Speed (Empty), mph or km/hr	60	96.6
Number of Trips/Train-Year (4)	510	
Locomotive Power Required, hp or kw (5)	5.54×10^5	4.13×10^5
Net Weight Originated/Day, short or metric tons	0.217×10^6	0.197×10^6
Net Weight Originated/Year, short or metric tons	79.2×10^6	71.8×10^6
Percent Illinois 1972 Production to Power Plants (6)	152%	
Average Gross Weight/Year (Passing Single Track), short or metric tons	3.08×10^7	2.79×10^7
Net Ton-Miles/Car-Year or Metric Ton-km/Car-Year	1.20×10^7	1.75×10^7
Net Ton-Miles/Year or Metric Ton-km/Year	1.98×10^{10}	2.89×10^{10}
Total Net Ton-Miles or Metric Ton-km	3.96×10^{11}	5.78×10^{11}
Operating Crew/Train (7)	4	
Total Crew Man-Hours/Year (8)	5.78×10^5	

Table 2 Capital Cost of Transportation

Roadbed (9)	$\$9.50 \times 10^{8}$
Coal Cars @ $17,000 each	2.81×10^{7}
Locomotives (10)	5.54×10^{7}
Total	$\$1.03 \times 10^{9}$

Table 3 Annual Costs

1. Fixed Charge on Debt (11)		
A. Roadbed		
1. Rate Base	$\$63.6 \times 10^{6}$	
2. Federal Income Tax @ 28% of Rate Base	17.8×10^{6}	
3. Depreciation @ 4% of Capital Cost	38.0×10^{6}	
		$\$119.4 \times 10^{6}$
B. Coal Cars		
1. Rate Base	1.89×10^{6}	
2. Federal Income Tax @ 28% of Rate Base	0.53×10^{6}	
3. Depreciation @ 4% of Capital Cost	1.12×10^{6}	
		3.5×10^{6}
C. Locomotives		
1. Rate Base	3.71×10^{6}	
2. Federal Income Tax	1.04×10^{6}	
3. Depreciation	2.22×10^{6}	
		7.0×10^{6}
2. Roadbed Maintenance (12)		5.4×10^{6}
3. Coal Car Maintenance (13)		3.0×10^{6}
4. Locomotive Maintenance (14)		6.4×10^{6}
5. Crew @ $10/hour		5.88×10^{6}
6. Administration @ 25% of Crew Cost		1.5×10^{6}
7. Fuel for Locomotives (15)		10.0×10^{6}
8. Total		$\$162.0 \times 10^{6}$

Cost (¢) per Ton-Mile: 0.818¢/Net Ton-Mile

ASSUMPTIONS USED IN ECONOMIC ANALYSIS (Tables 1, 2, and 3)

1. Coal hopper cars of A242 steel are employed because of their low maintenance and reasonable tare weight. The hopper cars weight 28 tons empty and typically carry 103.5-ton loads. Their cost was $15,000 in 1971, and are raised to $17,000 to cover inflation, etc., [30].
2. The number of coal cars is based on 15 100-car trains with a 10 percent reserve to cover breakdowns.
3. The average loaded train speed is assumed to be 50 mph, and a suitable locomotive horsepower chosen. The 60-mph average empty train speed is chosen as a reasonable upper limit in spite of extra power available. If rolling stock and track could stand higher speeds, the high speed power available with typical empty train weights raises the horsepower/weight figure by a factor of 3 to 4.
4. At speeds of 50 mph for a loaded train and 60 mph for an empty train, the travel times is 5 and 4.17 hours, respectively. Loading, unloading, and minor maintenance consumes 8 hours, yielding a round trip time of 17.2 hours or 510 trips per year.
5. Locomotive horsepower is to be sufficient to negotiate ruling grades of not more than 1 percent at speeds high enough to allow a 50 mph average speed when loaded. Power at rail/train weight versus speed curves are provided by Dellacononica. A power-to-weight ratio of 1.3 kw/ton at the rail allows up to 70 mph on a level road and

between 20 and 30 mph on a one percent grade [15]. This should easily provide for 50 mph average speeds over an improved roadbed in Illinois. The following calculation converts (kw/ton in Fig. 1) to engine horsepower per ton train weight:

$$\left[1.3 \ \frac{\text{kw (rail)}}{\text{ton (train)}}\right]\left[\frac{\text{1 hp (rail)}}{\text{0.7457 kw (rail)}}\right]\left[\frac{\text{1 hp (engine)}}{\text{0.77 hp (rail)}}\right] = 2.26 \ \frac{\text{hp(engine)}}{\text{ton (train)}}$$

Locomotive engine hp/ton locomotive weight is based on a figure obtained by averaging the horsepower/weight values of the following: (1) a 3,000 hp GE, (2) a 2,600 hp GE, (3) a 4,000 hp MLW, and (4) a 2,400 hp MLW. The respective hp/locomotive weight values for these locomotives were 19.73, 21.56, 20.10, and 18.91 which averages to 20.08 engine hp/ton locomotive weight [19]. If the weight of the loaded cars, the engine hp/train weight ratio and the engine hp/locomotive weight ratio are known, then locomotive engine hp and weight, as well as total train weight, can be determined. Let H denote engine hp per train and L denote locomotive weight (tons) per train, then the following equations can be solved simultaneously.

$$2.26 = \frac{H}{13{,}150 + L}$$

$$20 = \frac{H}{L}$$

Solving yields

L = 1,679 tons, H = 33,570 hp, total train weight = 14,830 tons

If a 10 percent reserve of locomotives is assumed, then the total horsepower required for 16.5 trains is 554,000.

6. Illinois coal production in 1972 was 65.5 x 10^6 tons from 59 mines in 22 counties. 79.9 percent of 52.2 x 10^6 tons of this coal went to electric utility companies. For comparison purposes, this system would be capable of supplying 152 percent of the demand [31].

7. The train crew consists of an engineer, a conductor, and two brakemen on each of the 15 active trains as well as the 10 percent reserve of 1.5 trains.

8. Because the trains operate continuously, the following is a calculation of the man-hours consumed:

$$\left[\frac{4\text{ men}}{\text{crew}}\right]\left[16.5\text{ crews}\right]\left[\frac{365\text{ days}}{\text{year}}\right]\left[\frac{24\text{ hours}}{\text{day}}\right] = 5.78 \times 10^5\ \frac{\text{man-hours}}{\text{year}}$$

9. Construction costs of 600 miles of double track is based on an estimate for a proposed North Carolina railroad [32]. Cost per mile for roadbed only was \$1.241 x 10^6. Including the cost of signaling, communications, terminals, and stations, the cost rises to \$1.584 x 10^6 per mile. This system was designed to avoid any large elevation gradients; thus, it is not radically different from Illinois terrain. Construction, however, would be more difficult due to the terrain in North Carolina. High land purchase costs and urban route restrictions in Illinois could offset this factor.

10. The cost of locomotives is assumed to be \$100 per engine-hp. This is based on a 1967 figure of \$82.6/engine-hp [24c]. To supply their Monroe power plant, Detroit Edison spent \$96.7/engine-hp for their 3,000 hp locomotives in 1970 [12].

11. The amortization period is assumed to be 20 years. Total capital is split into 55 percent debt and 45 percent equity. Interest on the debt is 9 percent, and interest on the equity is 15 percent [33]. The return on the rate base is as follows:

$$(0.55)(0.09) + (0.45)(0.15) = 0.117 \text{ or } 11.7\%$$

This is approximated at 12 percent which yields a series present worth factor of 7.469. The average rate base is one-half of capital investment (roadbed--\$4.75 x 10^8; cars--\$1.41 x 10^7; and locomotives--\$2.77 x 10^7). Federal income tax is assumed to be 28 percent of the rate base and depreciation is 4 percent of total capital investment.

12. The cost to replace one mile of single track (including ties and ballast) was estimated by Hay to be \$125,000 [17]. For a double track, a reasonable estimate would be \$225,000. In 1965, Hay indicated that average service life of railroad rails was 6.0 x 10^8 gross tons or roughly 25 years under average conditions [34]. In this case, annual gross tons passing each section of track is 3.08 x 10^8 gross tons which, employing the above estimate, yields a rail wearout time of 19.5 years. It is likely that rail wearout is close to a linear function of gross tonnage, once a fairly large gross tonnage is reached. Ties and ballast typically need replacing less frequently than rails on a high usage line; thus, a wearout figure of 25 years (or 4.0 percent of \$225,000 or \$9,000 per mile of double track is employed as the annual track maintenance cost. This yields a cost per gross ton-mile of \$0.000146.

13. Clapp and Swan employed a maintenance cost of $1,000 per car-year in their model of A242 steel cars mentioned earlier [30]. This figure was based on an annual gross ton-mileage of 7.975×10^6 while the cars of the Illinois model reach an annual gross ton-mileage of 1.85×10^7 or 2.32 times as much. An estimate of $2,000 per car-year is made. The total cost of maintenance is based on 1,500 cars while the spare 150 cars are assumed to require no maintenance.
14. Locomotive maintenance cost can be estimated roughly from car maintenance cost. In 1972, Class I railroads spent $517 million on freight diesel locomotive repairs (not including yard locmotives) and $692 million on freight car repairs (a ratio of 0.747 locomotive dollars per freight car dollar). There were 52.5 freight cars per diesel locomotive; the freight cars averaged about 67.6 tons capacity each and the locomotives averaged about 2,000 horsepower each [35]. This equates to 0.563 locomotive horsepower per net ton-car capacity. Unfortunately, this is not the ratio for actual trains because the percentage of freight cars likely to be standing idle is much higher than the percentage of freight locomotives likely to be standing idle. It is probable that locomotive horsepower/net ton car capacity for actual trains will be more than double this figure or about 1.13 horsepower/net ton. This ratio is much higher for the Illinois model (3.24 horsepower/net ton) due to the higher speeds assumed. Taking into consideration the extra horsepower utilized on the Illinois model, it is

possible to arrive at a rough figure for locomotive maintenance dollar per car maintenance dollar of 2.14.

15. Annual locomotive fuel costs are calculated by two methods. The first evaluation is taken from 1971 Transportation Statistics data [22] which yield \$0.0004846/net ton-mile freight fuel expenditures. Using the fuel price indices from the 1974 Edition of Railroad Facts, the rise in fuel costs from 1971 to 1973 can be estimated. The 1971 index was 114.6 and the 1973 index was 136.5, yielding an increase of 19.1 percent [22]. Hence, the fuel cost (1973 index) is as follows:

$$\left[1.191\right]\left[\frac{\$0.0004846}{\text{net ton-mile}}\right]\left[1.98 \times 10^{10}\ \text{net ton-miles}\right] = \$1.14 \times 10^{7}/\text{year}$$

The second evaluation is based on the brake specific fuel consumption of a 0.42-lbm/bhp-hr for a locomotive diesel [16]. Assume that the density of diesel fuel is 6.52 lbm/gallon and that on the average, one-half of the locomotive's horsepower is being used. Assuming negligible fuel consumption at loading and unloading sites, annual fuel consumption is as follows:

$$\left[\frac{0.42\ \text{lbm}}{\text{bhp-hr}}\right]\left[\frac{1}{6.52\ \text{lbm/gal}}\right]\left[\frac{33{,}570}{3}\ \frac{\text{bhp}}{\text{train}}\right]\left[15\ \text{trains}\right]\left[9.2\ \frac{\text{hrs}}{\text{trip}}\right]$$

$$\left[510\ \frac{\text{trips}}{\text{year}}\right] = 5.07 \times 10^{7}\ \text{gallons/year}$$

In 1971, diesel fuel cost 10.88¢/gallon [23]. The 1974 price index* was not available; however, Hay estimated a price increase of from 5 to 6 cents per gallon [17]. This increase would bring the price to at least 18 cents per gallon or an annual fuel cost of $\$9.13 \times 10^{6}$. If the first cost figure were adjusted to 1974 by this method, the cost would be $\$1.58 \times 10^{7}$. For the

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*27 cents per gallon, December 1, 1974.

purposes of this scenario, a figure of \$1.00 x 10^7 will be utilized.

Utilizing the assumed speeds of 50 mph (loaded) and 60 mph (empty), one finds eight of the 15 trains occupying the 600 miles of double track at any given time. The 100 coal car unit trains have over 30,000 horsepower or roughly 10 locomotives at 3,000 horsepower each. Assuming that a coal car or locomotive is roughly 60 feet in length, a 100-car train yields a train length of 6,600 feet or 1.25 miles. Hence, only 10 miles of the 1,200 miles of single track are actually occupied by unit coal trains. Obviously, the track is very underused and could easily support a large increase in capacity.

Assuming a signal block length of 1.5 miles and one train for every two blocks (one train every three miles) yields a maximum density of 400 trains covering the 600 miles of double track. Unfortunately, this capacity could not possibly be sustained by the branch lines off the main line or the main line would become overloaded as it neared the consumption point. Depending on the location and the number of branch lines feeding into the main line, there would have to be a traffic reduction in the southern portion of the main line too. If the main line is 350 miles long and the 250 miles of branch lines are composed of ten evenly spaced branches which carry equal traffic, the following conclusions can be drawn: (1) Each branch line carries one-tenth the maximum track capacity. (2) Train density on the main line increases linearly from zero to maximum track capacity at the consumption point. (3) Train density is the same on the return route as the supply route. Hence, there is a branch line density of one train every 30 miles and an average main line density of one train every six miles. The entire 600 miles of double track could then support 133.3 trains (or one train) every nine miles, i.e., 16.7 times the capacity originally provided by coal trains.

In order to lower the ton-mile costs of coal, it would be necessary to allow other freight (e.g., grain which could also move from central collection points via unit trains) to utilize the 1,200 miles of track. High usage such as this could easily reduce the ¢/ton-mile figure to below 0.5¢/ton-mile. With increased utilization of the track, the cost of new roadbed construction would eventually become less of a cost factor. In the present model with 15 trains, the new roadbed (accounting for almost 75 percent of the annual cost of operation) is definitely the largest expenditure. For example, assume that track utilization was increased ten times, all expenses except new roadbed costs would be ten times their original value and the total yearly ton-miles would be ten times greater. The new roadbed cost would now consume only slightly over 20 percent of the annual expenditures. The ton-mile cost would fall from 0.818¢ per ton-mile to 0.28¢ per ton-mile.

Assume that an operation is supplied by 32 mines of 2.5 million tons yearly average capacity and that coal is delivered to eight large electric utility plants, each capable of burning 10 million tons per year average. Coal gasification facilities could later be substituted for electric utility plants in the supply model. Gasification plants probably have a greater average coal usage than most power plants and hence are better suited to this concentrated delivery. Coal unloading facilities, if properly synchronized, could unload one unit train at a time; hence, unloading rates in the range presently utilized would be satisfactory (3,000 to 6,000 tph). On the average, there are eight trains in route at all times; the other seven trains are loading, unloading, or in servicing sites. Allotting four hours for loading, three hours for unloading, and one hour for service time, there are approximately 3.5 trains loading, 2.5 trains unloading, and one train in servicing. With eight plants available and only 2.5 trains being unloaded at any one time, the unloading capacity is far from the practical limit. With 32 mines and 3.5 trains loading at a time, the loading facilities are even further from the practical limit than the unloading facilities. The number of trains at loading sites could be increased by a factor of 9, and the number of trains at unloading sites could be increased by a factor of about 3 (assuming proper synchronization).

6. COMPUTER MODEL FOR PRICING

The computer unit train model was formulated using the Illinois model as a framework. An attempt was made to quantify all cost parameters including loading and unloading costs. The values in some cases are only rough estimates and may not reflect actual cost data. The costs as well as other parameters are inputed with the use of NAMELIST. The reader may wish to substitute his own values. This can be accomplished by merely changing the NAMELIST values on the data cards. Data employed in each analysis is printed out before the cost chart. The 17 yearly cost items, the total yearly cost, and the dollar cost per ton-mile (including loading and unloading costs) comprise the cost chart. Three different degrees of rail renewal are encompassed in each chart:

1. Totally new roadbed,
2. New rail and ties, and
3. Minor track upgrade involving only replacement of damaged ties or rails.

Two different loaded train speeds are also employed, 30 mph and 50 mph. In both cases, the average empty train speed remains 60 mph although the locomotives may be capable of higher speeds. Extrapolating from Fig. 1, the horsepower at the rail per gross ton weight was approximated for both cases. A 50-mph loaded train requires 1.743 horsepower per ton gross weight while a 30-mph loaded train requires only 0.805 horsepower per ton gross weight. All variables utilized in the program are defined with comment statements at the beginning (input values) and throughout the program body as they occur.

```
      $JØB
      C
      C  ***** CØMPUTER MØDEL FØR FIXING CØAL UNIT TRAIN RATES *****
      C
1          DIMENSIØN B(5)
2          DIMENSIØN D(20,5)
3          DIMENSIØN C(4,19)
      C
4          NAMELIST/INPUT/YTØN,XMILE,RCØST,RSPWF,CCØST,VLD,VEMP,CCAP,CSPWF,
         1XCØST,HPRAL,CNUM,TIME,XSPWF,RMCT,CTARE,CGTMC,XGTMC,CHCST,XCREW,
         1FCØST,TMILE,CRES,XRES,CWRES,FITP,DEPR,ZCØST,UCØST,ZSIZE,USIZE,
         1ZSPWF,ZLAB,ULAB,ZUHLC,ZØCT,UØCT
      C YTØN IS THE TØTAL YEARLY NET-TØNS
      C XMILE IS THE ØNE WAY TRIP MILEAGE
      C RCØST IS THE RØAD CØNSTRUCTIØN CØST PER MILE
      C RSPWF IS THE SERIES PRESENT WØRTH FACTØR FØR THE AMØRTIZATIØN PERIØD ØF RØAD
      C CCØST IS THE PURCHASE CØST PER CØAL CAR
      C VLD IS THE AVERAGE VELØCITY ØF THE LØADED TRAIN
      C VEMP IS THE AVERAGE VELØCITY ØF THE EMPTY TRAIN IN MILES PER HØUR
      C CCAP IS THE CØAL CAR CAPACITY IN TØNS NET WEIGHT
      C CSPWF IS THE SPWF ØF THE CØAL CARS
      C XCØST IS THE LØCØMØTIVE CØST PER ENGINE HØRSEPØWER
      C HPRAL IS THE  HØRSEPØWER AT THE RAIL PER TØN GRØSS WEIGHT
      C CNUM IS THE NUMBER ØF CARS PER TRAIN
      C TIME IS THE TØTAL TIME FØR LØADING, UNLØADING AND MAINTENANCE IN HRS.
      C XSPWF IS THE SPWF ØF THE LØCØMØTIVES
      C RMCT IS THE RØAD MAINTENANCE CØST PER GRØSS TØN-MILE
      C CTARE IS THE EMPTY CAR WEIGHT ØR TARE WEIGHT IN TØNS
      C CGTMC IS THE CAR MAINTENANCE CØST PER GRØSS TØN-MILE
      C XGTMC IS THE LØCØMØTIVE MAINTENANCE CØST PER GRØSS TØN-MILE
      C CHCST IS THE TRAIN CREW HØURLY WAGE IN DØLLARS
      C XCREW IS THE NUMBER ØF CREW MEMBERS PER TRAIN
      C FCØST IS THE CØST PER GRØSS TØN-MILE FØR FUEL
      C TMILE IS THE TØTAL MILES ØF TRACK THAT MUST BE CØNSTRUCTED
      C CRES IS THE PERCENT ØF ACTIVE CØAL CARS KEPT IN RESERVE
      C XRES IS THE PERCENT ØF ACTIVE LØCØMØTIVES KEPT IN RESERVE
      C CWRES IS THE           C CWRES IS THE PERCENT ØF ACTIVE TRAIN CREW IN RESERVE
      C FITP IS THE FEDERAL INCØME TAX PERCENT ØF  RATE BASE
      C DEPR IS THE DEPRECIATIØN PERCENT ØF TØTAL CAPITAL
      C ZCØST IS THE LØADING EQUIPMENT CØST PER FACILITY
      C UCØST IS THE UNLØADING EQUIPMENT CØST PER FACILITY
      C ZSIZE IS THE LØADING FACILITY YEARLY CAPACITY IN TØNS
      C USIZE IS THE UNLØADING FACILITY YEARLY CAPACITY IN TØNS
      C ZSPWF IS THE SPWF ØF LØADING ØR UNLØADING FACILITIES
      C ZLAB IS THE NUMBER ØF MEN REQUIRED AT LØADING SITE
      C ULAB IS THE NUMBER ØF MEN REQUIRED AT THE UNLØADING SITE
      C ZUHLC IS THE HØURLY CØST ØF LABØR AT LØADING ØR UNLØADING SITE
      C ZØCT IS THE YEARLY ØPERATING CØST ØF A SINGLE LØADING FACILITY
      C UØCT IS THE YEARLY ØPERATING CØST ØF A SINGLE UNLØADING FACILITY
      C
5          DATA C/'RØAD','    ','    ','    ','CARS','    ','    ','    ',
         1'LØCØ','MØTI','VES ','    ','LØAD',' FAC','ILIT','Y   ','UNLØ',
         1'AD F','ACIL','ITY ','INCØ','ME T','AX. ','    ','DEPR','ECIA',
         1'TIØN','    ','RØAD',' MAI','NT. ','    ','CAR ','MAIN','T.  ',
         1'    ','LØCØ','. MA','INT.','    ','TRAI','N CR','EW  ','    ',
         1'TRAI','N AD','MIN.','    ','TRAI','N FU','EL  ','    ','LØAD',
         1' LAB','ØR  ','    ','UNLØ','AD L','ABØR','    ','LØAD',' ØPE',
         1'R.  ','    ','UNLØ','AD Ø','PER.','    ','TØTA','L CØ','ST  ',
         1'    ','S CØ','ST/T','ØN-M','ILE '/
*EXTENSIØN*  LIMIT ØF 5 CØNTINUATIØN CARDS EXCEEDED
```

```
      DØ 300 KK= 1,7
      DØ 200 J = 1,5
      READ (5,INPUT)
      WRITE (6,INPUT)
      B(J) = RCØST
C YNTM IS THE TØTAL YEARLY NET TØN-MILES
      YNTM = YTØN * XMILE
C YTRIP IS THE NUMBER ØF TRIPS PER TRAIN PER YEAR
      YTRIP = 8760.0/(XMILE/VEMP + XMILE/VLD + TIME)
C TCAR IS THE TØTAL NUMBER ØF CARS REQUIRED EXCLUDING SPARES
      TCAR = YTØN/(CCAP * YTRIP)
C TNUM IS THE TØTAL NUMBER ØF TRAINS REQUIRED INCLUDING SPARES
      TNUM = TCAR/CNUM
C HPTR IS THE LØCØMØTIVE HØRSEPØWER REQUIRED PER TRAIN
      HPTR = 20*(HPRAL*(CTARE+CCAP)*CNUM)/(15.4-HPRAL)
C YGTM IS THE TØTAL YEARLY GRØSS TØN-MILES
      YGTM = (HPTR/10.0 + (2.0 * CTARE + CCAP)*CNUM)/(CCAP*CNUM)*YNTM
C CRCT IS THE TØTAL CAPITAL RØAD CØST
      CRCT = RCØST * TMILE
C CCCT IS THE TØTAL CAPITAL CØST FØR CARS
      CCCT = CCØST * TCAR * (1.0 + CRES)
C CLCT IS THE TØTAL CAPITAL CØST FØR LØCØMØTIVES
      CLCT = XCØST * HPTR * TNUM * (1.0 + XRES)
C YRCT IS THE YEARLY RØADBED CØST
      YRCT = CRCT/(2.0 * RSPWF)
C YCCT IS THE YEARLY CØAL CAR CØST
      YCCT = CCCT/(2.0 * CSPWF)
C YLCT IS THE YEARLY LØCØMØTIVE CØST
      YLCT = CLCT/(2.0 * XSPWF)
C ZNUM IS THE  NUMBER ØF LØADING SITES REQUIRED
      ZNUM = YTØN/ZSIZE
C UNUM IS THE NUMBER ØF UNLØADING SITES REQUIRED
      UNUM = YTØN/USIZE
      CZCT = ZNUM * ZCØST
      CUCT = UNUM * UCØST
C YZCT IS THE YEARLY LØADING EQUIPMENT CØST
      YZCT = CZCT/(2.0 * ZSPWF)
C YUCT IS THE YEARLY UNLØADING EQUIPMENT CØST
      YUCT = CUCT/(2.0 * ZSPWF)
C FITCT IS FEDERAL INCØME TAX ØN RØADBED, CARS, LØCØMØTIVES AND HANDLING FAC.
      FITCT = (YRCT + YCCT + YLCT + YZCT + YUCT) * FITP
C DEPCT IS CØST ØF DEPRECIATIØN ØN RØADBED, CARS, LØCØMØTIVES AND HANDLING FAC.
      DEPCT =  (CRCT + CCCT + CLCT + CZCT + CUCT) * DEPR
C YRMCT IS THE TØTAL YEARLY RØAD MAINTENANCE CØST
      YRMCT =  RMCT *  YGTM
C YCMCT IS THE TØTAL YEARLY CØAL CAR MAINTENANCE CØST
      YCMCT =  CGTMC * YNTM * (2.0*CTARE + CCAP)/CCAP
C YLCMT IS THE TØTAL YEARLY LØCØMØTIVE MAINTENANCE CØST
      YLMCT = XGTMC * YGTM
C YCWCT IS THE YEARLY TRAIN CREW CØST
      YCWCT = 8760.0 * CWCST * XCREW * (1.0 + CWRES) * TNUM
C YACT IS THE YEARLY ADMINISTRATIØN CØST FØR TRAINS
      YACT = .25 * YCWCT
C YFCT IS THE TØTAL YEARLY LØCØMØTIVE FUEL CØST
      YFCT = FCØST * YGTM
C YZLCT IS THE YEARLY LØADING LABØR CØSTS
      YZLCT = ZLAB * ZNUM * ZUHLC * 8760.0
C YULCT IS THE YEARLY UNLØADING LABØR CØSTS
      YULCT = ULAB * UNUM * ZUHLC * 8760.0
C YZØCT IS THE YEARLY TØTAL ØPERATING CØST ØF ALL LØADING FACILITIES
```

```
      YZØCT = ZØCT * ZNUM
C YUØCT IS THE YEARLY TØTAL ØPERATING CØST ØF ALL UNLØADING FACILITIES
      YUØCT = UØCT * UNUM
C YCT IS THE TØTAL YEARLY CØST ØF ØPERATIØN ØF THE UNIT TRAIN SYSTEM
      YCT  =  YRCT+YCCT+YLCT+YZCT+YUCT+FITCT+DEPCT+YRMCT+YCMCT+YLMCT+
     1 YCWCT+YACT+YFCT+YZLCT+YULCT+YZØCT+YUØCT
C YNTMC IS THE CØST ØF ØPERATIØN ØF THE UNIT TRAIN SYSTEM PER TØN-MILE
C     INCLUDING LØADING AND UNLØADING CØSTS
      YNTMC = YCT/YNTM
      D(1,J) = YRCT
      D(2,J) = YCCT
      D(3,J) = YLCT
      D(4,J) = YZCT
      D(5,J) = YUCT
      D(6,J) = FITCT
      D(7,J) = DEPCT
      D(8,J) = YRMCT
      D(9,J) = YCMCT
      D(10,J) = YLMCT
      D(11,J) = YCWCT
      D(12,J) = YACT
      D(13,J) = YFCT
      D(14,J) = YZLCT
      D(15,J) = YULCT
      D(16,J) = YZØCT
      D(17,J) = YUØCT
      D(18,J) = YCT
      D(19,J) = YNTMC
200   CØNTINUE
      WRITE (6,94) YTØN,XMILE,TMILE,YNTM, B(1)
94    FØRMAT (1H1/////T5,'NET TØNS/YEAR',T22,'ØNEWAY TRIP MILES',T43,
     1'TØTAL TRACK MILES',T62,'NET TØN-MILES/YEAR',T87,'S/MILE NEW RØAD'
     1/ 5(5X, 1P1E15.4))
      WRITE (6,96)
96    FØRMAT (1H0,T26,'NEW RØADBED',T46,'NEW RØADBED',T64,
     1'NEW RAIL &TIES',T84,'NEW RAIL & TIES',T105,'TRACK UPGRADE'/
     1T2,'YEARLY CØSTS',T26,
     1'50 & 60 MPH',T46,'30 & 60 MPH',T66, '50 & 60 MPH',T86,
     1'30 & 60 MPH',T106,'30 & 60 MPH'/)
      WRITE (6,100) ((C(L,I), L=1,4),(D(I,K), K= 1,5), I=1,19)
100   FØRMAT(19(1H ,4A4,4X,5(1X, F18.6,1X)/))
      WRITE (6,120)
120   FØRMAT (1H1,T2,'END')
300   CØNTINUE
      STØP
      END
```

```
          SENTRY
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,PCØST=   0.1580000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.1580000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=

   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.2250000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.2250000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.3000000E 05,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
```

```
   NET TONS/YEAR    ØNEWAY TRIP MILES    TØTAL TRACK MILES  NET TØN-MILES/YEAR      $/MILE NEW RØAD
      7.9200E 07           2.5000E 02            6.0000E 02          1.9800E 10          1.5800E 06

                       NEW RØADBED          NEW RØADBED        NEW RAIL &TIES        NEW RAIL & TIES       TRACK UPGRADE
YEARLY CØSTS           50 & 60 MPH          30 & 60 MPH          50 & 60 MPH          30 & 60 MPH          30 & 60 MPH

RØAD                 63462300.000000      63462300.000000       9037354.000000       9037354.000000       1204980.000000
CARS                  1877220.000000       2241727.000000       1877220.000000       2241727.000000       2241727.000000
LØCØMØTIVES           3706500.000000       1912850.000000       3706500.000000       1912850.000000       1912850.000000
LØAD FACILITY          883652.100000        883652.100000        883652.100000        883652.100000        883652.100000
UNLØAD FACILITY       1060382.000000       1060382.000000       1060382.000000       1060382.000000       1060382.000000
INCØME TAX           19877200.000000      19477040.000000       4638229.000000       4238069.000000       2045005.000000
DEPRECIATIØN         42417950.000000      41564000.000000       9897983.000000       9044042.000000       4364042.000000
RØAD MAINT.           5392410.000000       4860059.000000       5392410.000000       4860059.000000       4860059.000000
CAR MAINT.            3295405.000000       3295405.000000       3295405.000000       3295405.000000       3295405.000000
LØCØ. MAINT.          5023067.000000       4527178.000000       5023067.000000       4527178.000000       4527178.000000
TRAIN CREW            5779935.000000       6902251.000000       5779935.000000       6902251.000000       6902251.000000
TRAIN ADMIN.          1444983.000000       1725562.000000       1444983.000000       1725562.000000       1725562.000000
TRAIN FUEL           10009190.000000       9021067.000000      10009190.000000       9021067.000000       9021067.000000
LØAD LABØR            3700223.000000       3700223.000000       3700223.000000       3700223.000000       3700223.000000
UNLØAD LABØR          1665100.000000       1665100.000000       1665100.000000       1665100.000000       1665100.000000
LØAD ØPER.            2639999.000000       2639999.000000       2639999.000000       2639999.000000       2639999.000000
UNLØAD ØPER.          3959999.000000       3959999.000000       3959999.000000       3959999.000000       3959999.000000
TØTAL CØST          176195300.000000     172898600.000000      74011480.000000      70714780.000000      56009360.000000
$ CØST/TØN-MILE              0.008899             0.008732             0.003738             0.003571             0.002829
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END
&INPUT
YTON=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.3160000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTON=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.3160000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTON=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.4500000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTON=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.4500000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTON=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.6000000E 05,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
```

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   NET TØNS/YEAR    ØNEWAY TRIP MILES    TØTAL TRACK MILES  NET TØN-MILES/YEAR       $/MILE NEW RØAD
        7.9200E 07          2.5000E 02           6.0000E 02          1.9800E 10            3.1600E 06

                         NEW RØADBED          NEW RØADBED         NEW RAIL &TIES       NEW RAIL & TIES        TRACK UPGRADE
YEARLY CØSTS             50 & 60 MPH          30 & 60 MPH          50 & 60 MPH          30 & 60 MPH          30 & 60 MPH

RØAD                 126924600.000000     126924600.000000      18074680.000000      18074680.000000       2509961.000000
CARS                   1877220.000000       2241727.000000       1877220.000000       2241727.000000       2241727.000000
LØCØMØTIVES            3706500.000000       1912850.000000       3706500.000000       1912850.000000       1912850.000000
LØAD FACILITY           883652.100000        883652.100000        883652.100000        883652.100000        883652.100000
UNLØAD FACILITY        1060382.000000       1060382.000000       1060382.000000       1060382.000000       1060382.000000
INCØME TAX            37646640.000000      37246460.000000       7148675.000000       6768513.000000          [illegible]
DEPRECIATIØN          80357950.000000      79484000.000000      15297950.000000      14444000.000000          [illegible]
RØAD MAINT.            5392410.000000       4860059.000000       5392410.000000       4860059.000000       4860059.000000
CAR MAINT.             3295405.000000       3295405.000000       3295405.000000       3295405.000000       3295405.000000
LØCØ. MAINT.           5023067.000000       4527178.000000       5023067.000000       4527178.000000       4527178.000000
TRAIN CREW             5779935.000000       6902251.000000       5779935.000000       6902251.000000       6902251.000000
TRAIN ADMIN.           1444983.000000       1725562.000000       1444983.000000       1725562.000000       1725562.000000
TRAIN FUEL            10009190.000000       9021067.000000      10009190.000000       9021067.000000       9021067.000000
LØAD LABØR             3700223.000000       3700223.000000       3700223.000000       3700223.000000       3700223.000000
UNLØAD LABØR           1665100.000000       1665100.000000       1665100.000000       1665100.000000       1665100.000000
LØAD ØPER.             2639999.000000       2639999.000000       2639999.000000       2639999.000000       2639999.000000
UNLØAD ØPER.           3959999.000000       3959999.000000       3959999.000000       3959999.000000       3959999.000000
TØTAL CØST           295346100.000000     292049400.000000      90979230.000000      87682490.000000      51271760.000000
$ CØST/TØN-MILE               0.014916             0.014750             0.004595             0.004428             0.002943
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END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.7900000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.7900000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.1325000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.1325000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.7920000E 08,XMILE=   0.2500000E 03,RCØST=   0.1500000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
```

```
NET TØNS/YEAR    ØNEWAY TRIP MILES    TØTAL TRACK MILES  NET TØN-MILES/YEAR      $/MILE NEW RØAD
      7,9200E 07           2,5000E 02           6,0000E 02          1,9800E 10          7,9000E 06

                      NEW RØADBED          NEW RØADBED         NEW RAIL &TIES      NEW RAIL & TIES      TRACK UPGRADE
YEARLY CØSTS          50 & 60 MPH          30 & 60 MPH          50 & 60 MPH          30 & 60 MPH          30 & 60 MPH

RØAD                 317311200,000000     317311200,000000      53219950,000000      53219950,000000       6024903,000000
CARS                   1877220,000000       2241727,000000       1877220,000000       2241727,000000       2241727,000000
LØCØMØTIVES            3706500,000000       1912850,000000       3706500,000000       1912850,000000       1912850,000000
LØAD FACILITY           883652,100000        883652,100000        883652,100000        883652,100000        883652,100000
UNLØAD FACILITY        1060382,000000       1060382,000000       1060382,000000       1060382,000000       1060382,000000
INCØME TAX            90954730,000000      90554620,000000      17009340,000000      16609180,000000       3394583,000000
DEPRECIATIØN         194097600,000000     193243600,000000      36297950,000000      35444000,000000       7244042,000000
RØAD MAINT.            5392410,000000       4860059,000000       5392410,000000       4860059,000000       4860059,000000
CAR MAINT.             3295405,000000       3295405,000000       3295405,000000       3295405,000000       3295405,000000
LØCØ. MAINT.           5023067,000000       4527178,000000       5023067,000000       4527178,000000       4527178,000000
TRAIN CREW             5779935,000000       6902251,000000       5779935,000000       6902251,000000       6902251,000000
TRAIN ADMIN.           1444983,000000       1725562,000000       1444983,000000       1725562,000000       1725562,000000
TRAIN FUEL            10009190,000000       9021067,000000      10009190,000000       9021067,000000       9021067,000000
LØAD LABØR             3700223,000000       3700223,000000       3700223,000000       3700223,000000       3700223,000000
UNLØAD LABØR           1665100,000000       1665100,000000       1665100,000000       1665100,000000       1665100,000000
LØAD ØPER.             2639999,000000       2639999,000000       2639999,000000       2639999,000000       2639999,000000
UNLØAD ØPER.           3959999,000000       3959999,000000       3959999,000000       3959999,000000       3959999,000000
TØTAL CØST           652799200,000000     649502900,000000     156965100,000000     153668400,000000      65058840,000000
$ CØST/TØN-MILE               0,032970             0,032803             0,007928             0,007761             0,003286
```

```
END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.1580000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.1580000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.2250000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.2250000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.3000000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
```

```
   NET TØNS/YEAR    ØNEWAY TRIP MILES   TØTAL TRACK MILES  NET TØN-MILES/YEAR      $/MILE NEW RØAD
       1.5840E 08           2.5000E 02          6.0000E 02          3.9600E 10          1.5800E 06

                       NEW RØADBED         NEW RØADBED        NEW RAIL &TIES .    NEW RAIL & TIES     TRACK UPGRADE
YEARLY CØSTS           50 & 60 MPH         30 & 60 MPH         50 & 60 MPH         30 & 60 MPH         30 & 60 MPH

RØAD                   63462300.000000     63462300,000000      9037354,000000      9037354,000000      1204980,000000
CARS                    3754441.000000      4483457,000000      3754441.000000      4483457,000000      4483457,000000
LØCØMØTIVES             7413001.000000      3825702,000000      7413001.000000      3825702.000000      3825702,000000
LØAD FACILITY           1767303.000000      1767303,000000      1767303.000000      1767303,000000      1767303,000000
UNLØAD FACILITY         2120764.000000      2120764,000000      2120764,000000      2120764,000000      2120764,000000
INCØME TAX             21984960,000000     21184650,000000      6145992,000000      5945676,000000      3752617,000000
DEPRECIATIØN           46915930,000000     45208040,000000     14395940,000000     12688070,000000      8008087,000000
RØAD MAINT,            10784810,000000      9720118,000000     10784810,000000      9720118,000000      9720118,000000
CAR MAINT,              6590815,000000      6590815,000000      6590815,000000      6590815,000000      6590815,000000
LØCØ, MAINT,           10046120,000000      9054357,000000     10046120,000000      9054357,000000      9054357,000000
TRAIN CREW             11559860,000000     13804500,000000     11559860,000000     13804500,000000     13804500,000000
TRAIN ADMIN,            2889967,000000      3451125,000000    . 2889967,000000      3451125,000000      3451125,000000
TRAIN FUEL             20018360,000000     18042120,000000     20018360,000000     18042120,000000     18042120,000000
LØAD LABØR              7400446,000000      7400446,000000      7400446,000000      7400446,000000      7400446,000000
UNLØAD LABØR            3330200,000000      3330200,000000      3330200,000000      3330200,000000      3330200,000000
LØAD ØPER,              5279998,000000      5279998,000000      5279998,000000      5279998,000000      5279998,000000
UNLØAD ØPER,            7919999,000000      7919999,000000      7919999,000000      7919999,000000      7919999,000000
TØTAL CØST            233239100,000000    226645800,000000    131055200,000000    124461800,000000    109756400,000000
$ CØST/TØN-MILE               0,005890            0,005723            0,003309            0,003143            0,002772
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END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.3160000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.3160000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.4500000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.4500000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.6000000E 06,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.3000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.8050000E 00,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
   0.1080000E-03,XGTMC=   0.1360000E-03,CHCST=   0.1000000E 02,XCREW=   0.4000000E 01,FCØST=   0.2710000E-03,TMILE=   0.6000000E 03,
CRES=   0.1000000E 00,XRES=   0.1000000E 00,CWRES=   0.1000000E 00,FITP=   0.2800000E 00,DEPR=   0.4000000E-01,ZCØST=
   0.5000000E 06,UCØST=   0.2000000E 07,ZSIZE=   0.3000000E 07,USIZE=   0.1000000E 08,ZSPWF=   0.7469000E 01,ZLAB=   0.2000000E 01,
ULAB=   0.3000000E 01,ZUHLC=   0.8000000E 01,ZØCT=   0.1000000E 06,UØCT=   0.5000000E 06,&END
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   NET TØNS/YEAR    ØNEWAY TRIP MILES   TØTAL TRACK MILES  NET TØN-MILES/YEAR      $/MILE NEW RØAD
        1,5840E 08         2,5000E 02          6,0000E 02          3,9600E 10          3,1600E 06

                        NEW RØADBED         NEW RØADBED        NEW RAIL &TIES      NEW RAIL & TIES      TRACK UPGRADE
YEARLY CØSTS            50 & 60 MPH         30 & 60 MPH         50 & 60 MPH          30 & 60 MPH         30 & 60 MPH

RØAD                 126924600.000000    126924600,000000     18074680,000000     18074680,000000      2409961,000000
CARS                   3754441.000000      4483457,000000      3754441,000000      4483457,000000      4483457,000000
LØCØMØTIVES            7413001.000000      3825702,000000      7413001,000000      3825702,000000      3825702,000000
LØAD FACILITY          1767303.000000      1767303,000000      1767303,000000      1767303,000000      1767303,000000
UNLØAD FACILITY        2120764.000000      2120764,000000      2120764,000000      2120764,000000      2120764,000000
INCØME TAX            39754410,000000     38954090,000000      9276443.000000      8476127,000000      4090011,000000
DEPRECIATIØN          84635930,000000     83128040.000000     19795930,000000     18088040,000000      8728087,000000
RØAD MAINT.           10784810.000000      9720118,000000     10784810,000000      9720118,000000      9720118,000000
CAR MAINT.             6590815.000000      6590815,000000      6590815.000000      6590815,000000      6590815,000000
LØCØ. MAINT.          10046120.000000      9054357,000000     10046120,000000      9054357,000000      9054357,000000
TRAIN CREW            11559860,000000     13804500,000000     11559860,000000     13804500,000000     13804500,000000
TRAIN ADMIN.           2889967.000000      3451125.000000      2889967,000000      3451125,000000      3451125,000000
TRAIN FUEL            20018360.000000     18042120,000000     20018360,000000     18042120,000000     18042120,000000
LØAD LABØR             7400446,000000      7400446,000000      7400446,000000      7400446,000000      7400446,000000
UNLØAD LABØR           3330200,000000      3330200,000000      3330200,000000      3330200,000000      3330200,000000
LØAD ØPER.             5279998,000000      5279998,000000      5279998,000000      5279998,000000      5279998,000000
UNLØAD ØPER.           7919999,000000      7919999,000000      7919999,000000      7919999,000000      7919999,000000
TØTAL CØST           352389100,000000    345796000,000000    148023000,000000    141429600,000000    112018800,000000
$ CØST/TØN-MILE               0,008899            0,008732            0,003738            0,003571            0,002829
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```
END
&INPUT
YTØN=   0.1584000E 09,XMILE=   0.2500000E 03,RCØST=   0.7900000E 07,RSPWF=   0.7469000E 01,CCØST=   0.1700000E 05,VLD=
   0.5000000E 02,VEMP=   0.6000000E 02,CCAP=   0.1035000E 03,CSPWF=   0.7469000E 01,XCØST=   0.1000000E 03,HPRAL=   0.1743000E 01,
CNUM=   0.1000000E 03,TIME=   0.8000000E 01,XSPWF=   0.7469000E 01,RMCT=   0.1460000E-03,CTARE=   0.2800000E 02,CGTMC=
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    NET TØNS/YEAR    ØNEWAY TRIP MILES    TØTAL TRACK MILES  NET TØN-MILES/YEAR       $/MILE NEW RØAD
         1.5840E 08           2.5000E 02           6.0000E 02          3.9600E 10          7.9000E 06

                         NEW RØADBED          NEW RØADBED         NEW RAIL &TIES      NEW RAIL & TIES      TRACK UPGRADE
YEARLY CØSTS             50 & 60 MPH          30 & 60 MPH          50 & 60 MPH          30 & 60 MPH          30 & 60 MPH

RØAD                   317311200.000000     317311200.000000      53219950.000000      53219950.000000       6024903.000000
CARS                     3754441.000000       4483457.000000       3754441.000000       4483457.000000       4483457.000000
LØCØMØTIVES              7413001.000000       3825702.000000       7413001.000000       3825702.000000       3825702.000000
LØAD FACILITY            1767303.000000       1767303.000000       1767303.000000       1767303.000000       1767303.000000
UNLØAD FACILITY          2120764.000000       2120764.000000       2120764.000000       2120764.000000       2120764.000000
INCØME TAX              93062560.000000      92262250.000000      19117100.000000      18316800.000000       5102195.000000
DEPRECIATIØN           198595600.000000     196887800.000000      40795920.000000      39088030.000000      10888070.000000
RØAD MAINT.             10784810.000000       9720118.000000      10784810.000000       9720118.000000       9720118.000000
CAR MAINT.               6590815.000000       6590815.000000       6590815.000000       6590815.000000       6590815.000000
LØCØ. MAINT.            10046120.000000       9054357.000000      10046120.000000       9054357.000000       9054357.000000
TRAIN CREW              11559860.000000      13804500.000000      11559860.000000      13804500.000000      13804500.000000
TRAIN ADMIN.             2889967.000000       3451125.000000       2889967.000000       3451125.000000       3451125.000000
TRAIN FUEL              20018360.000000      18042120.000000      20018360.000000      18042120.000000      18042120.000000
LØAD LABØR               7400446.000000       7400446.000000       7400446.000000       7400446.000000       7400446.000000
UNLØAD LABØR             3330200.000000       3330200.000000       3330200.000000       3330200.000000       3330200.000000
LØAD ØPER.               5279998.000000       5279998.000000       5279998.000000       5279998.000000       5279998.000000
UNLØAD ØPER.             7919999.000000       7919999.000000       7919999.000000       7919999.000000       7919999.000000
TØTAL CØST             709843100.000000     703250100.000000     214008900.000000     207415500.000000     118805900.000000
$ CØST/TØN-MILE                0.017925             0.017759             0.005404             0.005238             0.003000
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```

```
   NET TONS/YEAR    ONEWAY TRIP MILES    TOTAL TRACK MILES  NET TON-MILES/YEAR      $/MILE NEW ROAD
        7.9200E 08         2.5000E 02           6.0000E 02          1.9800E 11          1.5800E 06

                      NEW ROADBED          NEW ROADBED          NEW RAIL &TIES       NEW RAIL & TIES       TRACK UPGRADE
YEARLY COSTS          50 & 60 MPH          30 & 60 MPH          50 & 60 MPH          30 & 60 MPH           30 & 60 MPH

ROAD                  63462300.000000      63462300.000000      9037354.000000       9037354.000000        1204980.000000
CARS                  18772190.000000      22417260.000000      18772190.000000      22417260.000000       22417260.000000
LOCOMOTIVES           37064990.000000      19128490.000000      37064990.000000      19128490.000000       19128490.000000
LOAD FACILITY          8836524.000000       8836524.000000       8836524.000000       8836524.000000        8836524.000000
UNLOAD FACILITY       10603820.000000      10603820.000000      10603820.000000      10603820.000000       10603820.000000
INCOME TAX            38847130.000000      34845530.000000      23608140.000000      19606560.000000       17413480.000000
DEPRECIATION          82899820.000000      74360410.000000      50379820.000000      41840400.000000       37160410.000000
ROAD MAINT.           53924090.000000      48600570.000000      53924090.000000      48600570.000000       48600570.000000
CAR MAINT.            32954040.000000      32954040.000000      32954040.000000      32954040.000000       32954040.000000
LOCO. MAINT.          50230650.000000      45271770.000000      50230650.000000      45271770.000000       45271770.000000
TRAIN CREW            57799340.000000      69022490.000000      57799340.000000      69022490.000000       69022490.000000
TRAIN ADMIN.          14449830.000000      17255610.000000      14449830.000000      17255610.000000       17255610.000000
TRAIN FUEL           100091900.000000      90210650.000000     100091900.000000      90210650.000000       90210650.000000
LOAD LABOR            37002240.000000      37002240.000000      37002240.000000      37002240.000000       37002240.000000
UNLOAD LABOR          16651000.000000      16651000.000000      16651000.000000      16651000.000000       16651000.000000
LOAD OPER.            26400000.000000      26400000.000000      26400000.000000      26400000.000000       26400000.000000
UNLOAD OPER.          39599980.000000      39599980.000000      39599980.000000      39599980.000000       39599980.000000
TOTAL COST           689568700.000000     656621500.000000     567405000.000000     554438100.000000      539732400.000000
$ COST/TON-MILE              0.003483             0.003316             0.002967             0.002800              0.002726
```

7. UNIT TRAIN COORDINATION WITH OTHER TRANSPORTATION SYSTEMS

In many cases it is either mandatory from a practical standpoint or just economical to combine unit trains with other modes of coal transportation to achieve a satisfactory mine-to-consumer route. Probably the most common combination at present is barge with rail. Generally, barge traffic is cheaper because ships do not pay for repair of waterway locks, etc., and, where lengthy water routes exist, can be linked with the railroad to provide a relatively inexpensive yet complete supply line. This type of system is most applicable on the Mississippi and Ohio Rivers where barges carry millions of tons of coal annually. Generally, the arrangement is rail-to-barge rather than the reverse since few mines are located on water routes. Power plants, on the other hamd, are commonly situated on navigable waters. In 1969 about 63.4 million tons of coal (18.5 percent of the railborne total destined for domestic consumption) was joint rail and barge movement [35]. The joint rail and river barge movement amounted to about 34 million tons out of a total of 103 million tons carried by barge [36].

Before a decision can be made concerning whether to combine a particular rail route with water borne means,the cost saving per ton-mile of water transport over rail and the additional expense of transferring the coal must be evaluated. The typical high volume long distance unit trains have transport costs of approximately 0.6¢/ton-mile. Large volume , steady coal movements on inland rivers typically cost only 0.25¢/ton-mile; the average is probably about 0.3¢/ton-mile. However, barge rates for certain tributary rivers, where congestion in obsolete navigation facilities is serious, are reported to be as high as 0.7¢/ton-mile [1e]. Also, many water routes tend to be less direct than rail or pipeline routes. The total point-to-point transportation cost must be evaluated in these cases rather than the ton-mile costs. The facility to transfer coal from rail to barge is probably at least as complex as a typical rail loading facility, with possibly less storage capacity if train and barge schedules are synchronized. Generally, only one transfer is made as the cost of two transfers increases the transportation cost per ton too much when combined with the already lengthy route necessary for a combined mode system. Possible exceptions to this rule might be supply routes involving low sulfur coal from remote areas where the disadvantages of high transportation costs can be compensated for by the ability to meet sulfur emission standards. Some electric utilities are faced with the decision of whether to convert to more expensive, and now scarce, petroleum based fuels to meet air pollution standards or to go great distances for low sulfur coal to combine with their regional high sulfur coal supply.

Coal slurry pipeline is another possible mode of transportation that could be combined with unit trains. Unfortunately, the very nature of a coal slurry mixture makes it practically impossible to economically transfer it to unit trains. On the other hand, there does not seem to be any reason why unit trains could not feed into a coal slurry preparation plant. In most cases slurry transportation is economical only for very long distances because of the extremely high preparation and separation costs ($\$10^8$ investment in facility for a 12,000 ton/day system) [37]. If a significantly long portion of slurry pipeline is already in position and an extension of the route is required, it is usually less costly to construct more pipeline rather than try to rely on another mode of transportation to complete the route and hence sustain extra transfer charges. Because of this factor alone, slurry in combination with other systems is very rare if existent.

The newest and most versatile addition to coal supply systems is a pneumatic pipeline. Using an air suspension of coal particles usually less than 0.25 inch in diameter, a pneumatic pipeline can achieve significantly lower ton-mile costs than the slurry pipelines by avoiding the expensive preparation and separation costs. Whether it can provide costs under those of unit trains remains to be determined; however, its greatest advantage lies in its versatility. If a small capacity supply line is needed to complete an existing rail network, then a small inexpensive pipeline could be constructed rather than building a rail branch line which would not be sufficiently utilized to justify construction costs. Many times the only other alternatives are the use of conveyors or truck hauling (both of which suffer from extremely high ton-mile costs). Trucks are grossly inefficient in their fuel usage, while construction costs for conveyors can run as high as equivalent rail construction costs. For example, the Illinois Power Vermillion Power Station is supplied with coal from Zeigler Coal Company's Murdock Mine, 48 miles away. Coal is transported by 20-ton trucks at the rate of $1.83/ton or 3.81¢/ton-mile (many times the rail rate) [38]. For a 3.5 mile, 18,000 tons per day coal supply line, S. L. Soo has projected costs of 1.14¢ per ton-mile for a pneumatic line and 3.83¢ per ton-mile for a conveyor belt [39]. A large diameter pneumatic pipeline can also achieve the large capacity of a railroad where a link in the main supply line is required.

A pneumatic pipeline could be fed by a unit train without difficulty. If a pneumatic pipeline were feeding a unit train, some type of car covering might be necessary to avoid loss of coal fines (present to a lesser extent in large lump coal normally hauled on unit trains). A pneumatic pipeline-unit train combination could lower coal storage requirements at the interface facility compared to other combinations because of the pneumatic pipeline's continuous and rapid feed. Pneumatic lines could gather coal from small suppliers to feed large rail loading facilities or distribute coal at an unloading facility to smaller users. Another future application lies in feeding large coal gasification facilities from several unit trains. Typically, coal gasification operations will require much more coal than present single unloading operations can supply.

8. DISCUSSION

Although possibly adequate for today's coal supply system, the coal unit train system will have to improve significantly to meet tomorrow's overwhelming demand for coal as an alternative to oil for energy. Unit trains will probably remain the primary mover of coal, especially over high volume supply lines. Mixing rail shipments with barge or pneumatic pipeline can sometimes provide lower transport costs. A pneumatic pipeline would be particularly useful to move coal over short or low volume routes. It could be used either as a gathering line to supply a unit train or to distribute rail shipments.

In order to be economical in the future energy market, coal must be capable of moving swiftly and in large volumes. The largest impediment to this is the present condition of rail lines. In order to support higher rail speeds and loads, most tracks must receive more than token maintenance. A few feet of track, a handful of ties, and several tons of ballast will not be sufficient to upgrade a mile of track. Dollar expenditures for upgrading of at the very least six figures will be necessary on many lines to allow speeds of over 50 mph and net loads over 100 tons per car with conventional running gear. Capital expenditures in this range probably cannot be generated by railroads themselves and outside assistance will be a necessity. In areas where long steep grades or sharp curves are present, new earthwork, as well as new track, will be required, pushing the cost to almost that of building an all new railroad.

The computer program in Chapter 6 is sufficient to point out most of the cost factors involved and where optimization efforts might be directed. Further efforts in this area should include a closer identification of the variables that affect each cost item and their functional relationships. It remains to be seen what speeds and capacities should be employed.

If very high volumes of coal are moved, for example, coal to gasification facilities, it might even be economical to build all new railroads over some routes. This is indicated by the relatively low ton-mile cost of 0.59¢ for an Illinois model moving 158 million tons per year (only three times the 1972 Illinois coal production sold to electric utilities). This figure is based on a new road construction cost of $1.58 million per mile and speeds of 50 mph loaded and 60 mph empty. On the other hand, with a lower capacity of 79 million tons per year and double the road cost ($3.16 million per mile), the cost soars to 1.5¢ per ton-mile. These two costs per ton-mile estimates can be compared with an actual case. Averaging the ton-mile costs and the mileage for 13 western coal unit trains operated by the Burlington Northern Railroad in 1974 yields a cost of 0.673¢ per ton-mile over a distance of 913 miles [41]. Unit coal trains operating over shorter distances generally have much higher ton-mile costs as exemplified by the Missouri Pacific Railroad. For ten trains, the average cost was 1.31¢ per ton-mile over a distance of 89.3 miles [42]. Unit coal train rates are obviously inversely proportional to annual capacity and trip mileage. Their combined effect on ton-mileage could be plotted versus train rates as in the graph by Nathan Associates (see Fig. 3).

All the computer cost charts show that the 30-60 mph models

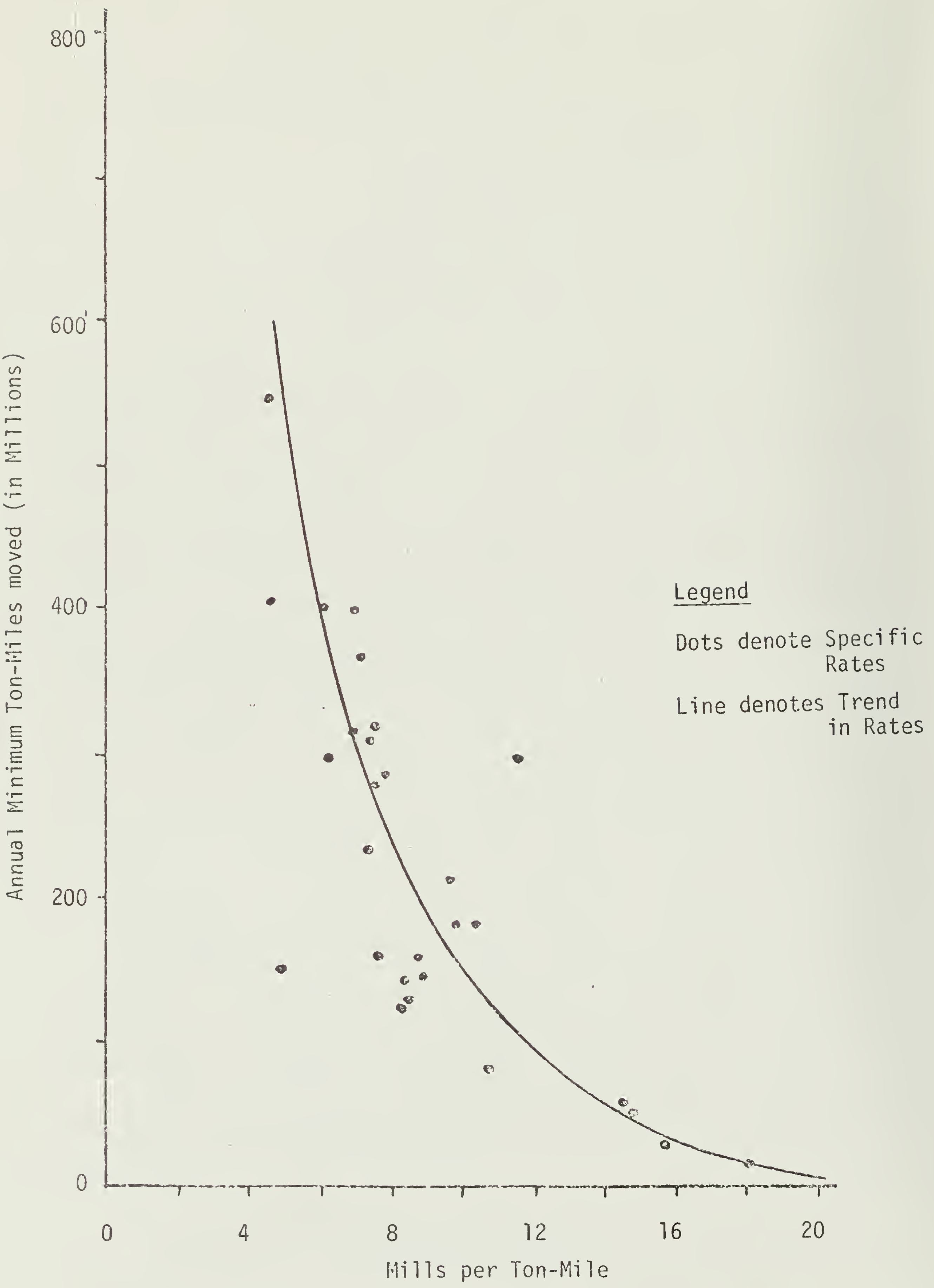

Figure 3 Representative Unit Train Tariffs for Eastern and Midwestern Movement [43]

are less expensive than the 50-60 mph models. This may or may not be relevent to the question of optimum train speed. Part of the reason for this is that the extra power available (especially in the 50 and 60 mph case) is not able to be utilized on the empty trains. Allowing much higher speeds on new roads might be more realistic and could alter this comparison significantly. If higher speeds and longer trains continue to be employed, higher horsepower locomotive units will probably be advantageous.

With the onset of the gasification of high sulfur coals (e.g., the majority of Illinois coal), long distance unit trains which were formerly necessary for supplying low sulfur coals from the west will be largely discontinued. Other national supply lines over 700 miles, once conceivable, may also fold. The flow of coal may revert to a regional level with the only interregional flow going to particular areas where coal is scarce. The possibilities are:

1. Illinois or Appalachian coal to the deep South and
2. Wyoming-Montana coal to the West coast.

However, these too may be uneconomical if the same energy can be transported in gaseous form by conventional pipeline.

9. SUMMARY

1. In Illinois, where a large expansion in coal production can be expected, a two-fold increase in south-north unit train shipments over 250 miles at 50 mph still yields a train density well within safe limits.

2. To obtain train speeds of 50 mph, significant upgrading of the current railroad system is needed. Current expenditures for maintenance do not insure a reliable and economical system.

3. In order to support large increases in the amount of coal shipped, locomotives of 10,000 horsepower unit capacity are advantageous for the most economical operation.

4. Rail shipments, mixed with barge, pneumatic pipeline, or both, can improve the economy of unit train operation especially in light of recent proposed rail abandonments. A pneumatic pipeline can be used either as a gathering line to supply a railroad unit train or to distribute rail shipments.

5. Increased reliance on coal gasification will radically alter the structure of interregional coal unit shipments. Most of these long distance shipments (over 700 miles) will cease to exist (e.g., low sulfur western coal to the Midwest).

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