THE INCREMENTAL COST OF TRANSPORTATION CAPACITY IN FREIGHT RAILROADING

The Tennessee Valley Authority
Knoxville, Tennessee

and

The Center For Business and Economic Research
Lewis College of Business
Marshall University
Huntington, West Virginia

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The Tennessee Valley Authority (TVA) and the Center for Business and Economic Research (CBER) have prepared this report at the request of the U.S. Army Corps of Engineers. However, the material and analysis contained herein are those of the authors and do not necessarily represent the positions of TVA, the CBER, or Marshall University.

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EXECUTIVE SUMMARY

The Principles and Guidelines used by the U.S. Army Corps of Engineers to evaluate the economic benefits of navigation projects direct analysts to assume that competing transport modes have sufficient capacity to accept any diverted traffic unless there is clear reason to suspect otherwise. In most settings, there is no reason to challenge this assumption. In the case of the Upper Mississippi basin, however, current traffic volumes and projected traffic growth are such that even marginal diversions could place significant volumes of additional traffic on the nation's rail system. Consequently, to simply assume that rail carriers could absorb this traffic without increasing the rates charged to all shippers is imprudent. It is for this reason that the Corps of Engineers has engaged the Tennessee Valley Authority in a lengthy investigation of railroad capacity and incremental rail capacity costs in the Upper Mississippi Basin.

TVA's analysis has consisted of two phases. Initially, the theoretical underpinnings that lead profit-maximizing firms to add new transport capacity were carefully examined. Additionally, this first phase contained a pilot study intended to determine whether or not Geographic Information

Systems (GIS) data could be effectively employed to analyze line-haul railroad capacity. Using Federal Railroad Administration (FRA) traffic density categories as the dependent variable, an ordered probit model was constructed to statistically associate traffic density with network link characteristics. This novel application of GIS data proved remarkably successful. The configuration and physical characteristics of a specific segment of railroad trackage proved to be an extremely reliable predictor of traffic density as measured by the FRA. Consequently, the decision was made to proceed with a more extensive investigation of railroad capacity in the Upper Mississippi basin. The second phase was intended to not only associate railroad traffic levels with route characteristics, but also gage the cost of incrementally expanding current capacity in order to accommodate additional traffic. Additionally, the Phase II analysis was to provide an, at least, cursory consideration of potential traffic diversions and terminal capacity.

In order to obtain a continuous measure of railroad traffic nearly one-half million records from the Surface Transportation Board's 1995 Carload Waybill Sample were routed over 75,000 distinct routings based on origin, destination, shipment length, and interchange locations. Once routed, associated car-loadings and predicted empty car movements were aggregated to measure the

traffic on each of roughly 2,500 specific route segments. These cross-sectional traffic volumes were once again statistically associated with the characteristics of the trackage that supports them and, again, this association proved to be very reliable.

Given the continuous relationship between traffic levels and route characteristics, it is possible to identify the set of physical alternatives that will increase track capacity. The next step in the analytical process is then to determine which of these alternatives will yield the desired new capacity at the lowest cost. In order to assess the cost of infrastructure improvements, TVA consulted with civil engineers from the University of Tennessee's Transportation Center. These engineers provided a generic set of costs for constructing or upgrading trackage to various standards under a number of different topographical conditions. In the final stage of the line-haul analysis these costs were combined with available alternatives to determine the incremental cost of line-haul capacity.

Unlike line-haul capacity, it is not possible to assess the potential of network terminals through cross-sectional statistical analysis. The capacity and limitations of each terminal are uniquely determined. Thus, a comprehensive analysis of terminal capacity would be both lengthy

and expensive. In the current context, this sort of extensive analysis is not possible. This does not mean, however, that the matter of terminal capacity is ignored. Current traffic flows were combined with potential traffic diversions to identify those terminal locations that might expect to see the greatest amount of traffic growth in the event that barge transport on the Upper Mississippi becomes economically unfeasible. While a number of locations throughout the Mid-West, Gulf-Coast, and Pacific Northwest regions could expect to see incremental increases in railroad traffic, the location that would seem to be most effected is St. Louis. Because many rail routings to the Gulf of Mexico pass through the St. Louis area and because the option of transloading rail shipments to barge at St. Louis is economically attractive, the diversion of traffic off of the Upper Mississippi River could place considerable pressure on terminal facilities at that location. No other significant terminal problems were identified.

The results of the analysis suggest that accommodating all the current Upper Mississippi barge traffic on the nation's rail system would require an incremental expenditure on capacity of between one-half and three-quarters of a cent per ton-mile. In order to assess the impacts of these costs on railroad rates it is necessary to compare incremental capacity costs to the capacity costs

presently embodied within rail rates. Rail rates vary considerable across commodities and origin/destinations pairs. Currently unit train shipments of dry-bulk commodities move at between 1.5 and 4 cents per ton-mile, while rates for smaller shipments of higher valued commodities may earn revenues of 6 or 7 cents per ton-mile. For 1996, the average per ton-mile rate across all rail movements was roughly 4.5 cents. Rule of thumb estimates suggest that average fixed costs equal about one-third of the average rate or about 1.5 cents per ton-mile. Thus, it would appear that the average variable costs for large volume shipments are extremely low and that revenues from some shipments may not cover all costs. Of the roughly 1.5 cents in per ton-mile fixed costs, it is estimated that perhaps as much as one cent reflects the cost of line-haul and terminal facilities. Any further division of fixed costs is impossible within the current context. When estimated incremental capacity costs are compared to the capital costs currently embodied within railroad rates, it would appear that this new capacity would sometimes lower extant rates and sometimes necessitate their increase. These results do not, however, provide the irrefutable evidence necessary to forego the traditional assumption of adequate railroad capacity.

SECTION 1

INTRODUCTION AND MOTIVATION

Traffic predictions developed as a part of *the Upper Mississippi Navigation Feasibility Study* indicate that the demand for surface transportation in the Upper Mississippi basin may double or even triple over the next fifty years. The economic Procedures and Guidelines used by the U.S. Army Corps of Engineers (Corps) to determine project benefits and costs reason that if inland navigation capacity is not expanded to meet this new demand, competing surface transport modes either possess or will add the capacity necessary to accommodate the new traffic.[1] As a consequence, it is possible to assume that any quantity of any transportation alternative can and will be made available with no significant increase in its unit price. Benefits and costs are to be calculated accordingly. These same Procedures and Guidelines do, however, provide for the relaxation or revision of this capacity assumption if there is sufficient reason to do so.

[1] See *Economic Principles and Guidelines for Water and Related Land Resources Implementation Studies*, U.S. Army Corps of Engineers, 1983, Section 2.6.11, p. 54.

In the specific case of Upper Mississippi basin navigation, there are several factors that have caused policy makers and transportation users to question the validity of the traditional assumption of available modal capacity - particularly with respect to rail transport. First, the volume of waterborne traffic projected to move to, from, and within the region is large relative to the traffic volumes currently observed on many other segments of the inland navigation system. Current Upper Mississippi tonnage is well in excess of 100 million tons each year. Further, both users and transportation planners are also concerned that the resurgence in rail traffic and rationalization of rail facilities evidenced over the past two decades has purged the rail system of the excess capacity that characterized the industry from the 1950s through the early 1980s. Industry publications are replete with stories describing current operational bottlenecks, related service problems, and railroad efforts to eliminate the conditions that currently constrain traffic.[2] Finally, some worry that the consolidations within railroading (from roughly

[2] Certainly, both line-haul and terminal congestion on the Union Pacific has garnered press coverage. Additionally, however, it is worth noting that various railroads, including the Union Pacific are spending considerable sums to increase capacity and eliminate bottlenecks. For example, the Burlington Northern-Santa Fe recently spent more than $100 million to reopen the Stampede Pass route across the Cascade Mountains in Washington State. Both BNSF and the UP are triple-tracking segments of their routes leading from the Powder River Basin and Norfolk-Southern and CSXT have pledged more than $300 million in capital improvements if their acquisition and division of Conrail is successful.

two dozen Class I carriers in 1980 to as few as seven in 1998) have resulted in an industry that is incapable of responding to demand growth even if the economic incentives that would normally signal a need for new capacity are present.[3]

If the typical capacity assumptions employed within the Corps methodology are inappropriate, the resulting analysis could significantly misstate the value of proposed navigation improvements. In particular, if rail carriers do not possess the capacity to accommodate diverted traffic; of if the cost of accommodation would increase overall rail rates, then the value of proposed navigation projects would be understated.[4] It is for this reason that the Tennessee Valley Authority (TVA) in conjunction with the St. Louis and Rock Island Districts of the U.S. Army Corps of Engineers has engaged in an 18-month examination of U.S. rail network capacity and incremental capacity costs.

[3] As this document is being prepared, it is likely but not certain that the Surface Transportation Board will approve the transaction through which Conrail assets are to be acquired by and divided between Norfolk Southern and CSX Transportation. If this transaction is approved, the number of U.S. owned Class I railroads will be reduced to six. Additionally both the Canadian National and the Canadian Pacific Rail System maintain an operational presence in the U.S.

[4] See, *The Incremental Cost of Transportation Capacity in Freight Railroads, Phase I Analysis,* U.S. Army Corps of Engineers, St. Louis District, May, 1997.

The remainder of this document is organized as follows: Section 2 provides a general description of extant rail capacity, as well as a discussion of those factors that determine specific route capacities. A model for estimating line-haul route capacity is developed in Section 3 and estimation results are also discussed within that section. Section 4 combines model estimation results, data detailing railroad construction costs, and information of a few select terminal locations to develop estimates of incremental rail capacity costs in the Upper Mississippi basin. Finally, Section 5 concludes the document with a few summary comments.

SECTION 2

U.S. RAILROAD CAPACITY

2.1 OVERVIEW

In 1995, U.S. railroads operated roughly 150,000 miles of track over which they moved 1.8 billion tons of freight an average of 756 miles to provide a total of more than 1.345 trillion ton-miles of transportation services. Of this total more than 527 million tons originated and/or terminated in the Upper Mississippi basin. Summary traffic statistics are reported in Table 2.1 below.

Aggregate statistics, however, cannot be used to adequately evaluate the relationship between barge transportation and the potential need for additional railroad capacity. To the contrary, capacity issues must be investigated by fully disaggregating the rail network and evaluating the capacity of each of the "links" that, together, form specific routes. Both the need for and the complexity of this "link-specific" analysis are made clear through a simple example.

Figure 2.1 portrays a simple network comprised of six nodes (A, B, C, . . .) and six links (AB, AC, BC, . . .). Together, these links form no less than 24 distinct two-way routings. Traffic along such a

Table 2.1

STCC	ILLINOIS	IOWA	MINNESOTA	MISSOURI	WISCONSIN	TOTAL
1	21,172,956	13,363,797	11,551,723	6,586,894	5,413,400	58,088,770
8	348,660	29,560		16,200		394,420
9	39,880			2,000		41,880
10	3,031,784	47,520	15,259,701	299,200	14,529,984	33,168,189
11	61,150,343	26,104,427	24,448,259	44,176,352	37,561,580	193,440,960
13	1,420,936	7,800				1,428,736
14	8,812,472	4,011,028	1,954,232	852,804	895,648	16,526,184
19	1,470,153		13,480			1,483,633
20	23,037,453	5,671,500	2,790,063	4,379,644	1,120,700	36,999,360
21	5,200		173,112	3,960		182,272
22	202,476	44,720	187,440	158,376	6,520	599,532
23	830,348		4,760	6,960		842,068
24	8,004,479	2,879,121	1,956,700	2,375,678	2,456,528	17,672,506
25	495,980			257,960	47,320	801,260
26	10,817,292	1,403,126	2,686,580	1,370,560	4,237,168	20,514,726
27	232,784		252,968	69,760		555,512
28	26,823,149	6,316,850	6,160,940	5,117,816	2,642,252	47,061,007
29	6,079,610	1,963,243	1,254,357	825,855	776,497	10,899,562
30	447,014		110,792	53,360	3,080	614,246
31	1,027,888		2,080	113,520		1,143,488
32	3,671,566	1,398,048	2,786,120	1,258,412	1,707,208	10,821,354
33	6,357,716	1,749,358	2,047,637	1,276,364	586,432	12,017,507
34	115,372		3,800	48,160		167,332
35	710,200	39,660	1,631,364	6,360	7,840	2,395,424
36	630,100	70,280	536,140	131,424	800	1,368,744
37	14,605,627	1,165,220	1,184,384	2,374,798	484,200	19,814,229

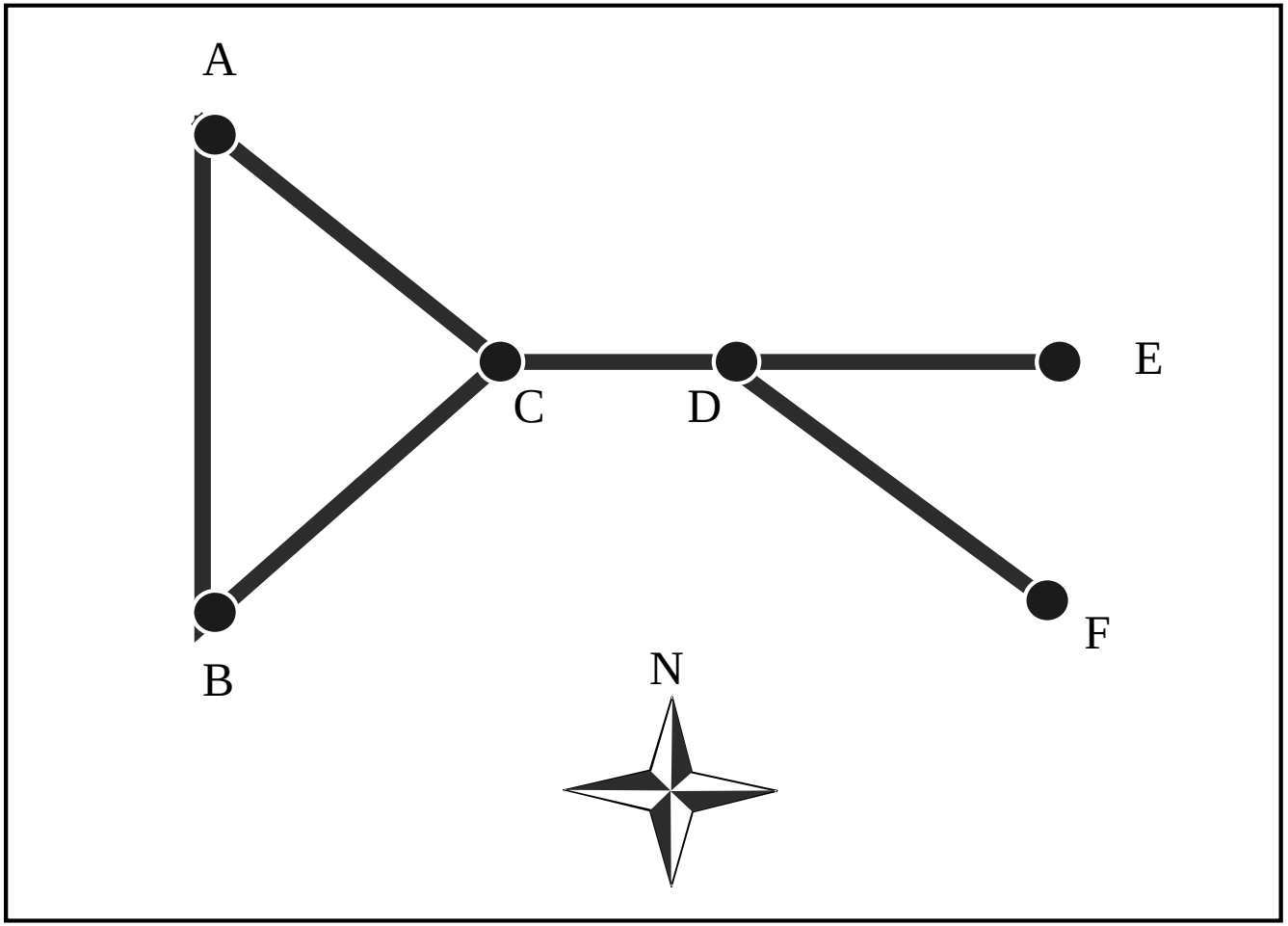
STCC	ILLINOIS	IOWA	MINNESOTA	MISSOURI	WISCONSIN	TOTAL
38	531,096			8,160		539,256
39	1,893,121		10,400	26,320		1,929,841
40	4,203,668	661,732	507,964	537,128	673,120	6,583,612
41	281,880		29,560	201,964	10,840	524,244
42	2,291,547	167,552	159,360	376,992	37,680	3,033,131
43	108,920	4,960		19,560		133,440
44	519,720		170,768	37,560		728,048
45	207,704		218,796	9,560		436,060
46	19,684,427	460,572	1,232,904	2,168,816	253,680	23,800,399
47	342,740			30,440		373,180
48	316,616			268,740		585,356
Grand Total	231,922,876	67,560,074	79,326,384	75,447,657	73,452,477	527,709,467

network could readily move from A to B, from B to F, or from C to E. There are, in fact 15 distinct origin destination pairs that are served by this network. Moreover, in nine cases, there is more than one way to connect a particular pair of points. For example, it is possible to route from A to D by simply going from A to C to D. Alternatively the AC link may be avoided by a routing from A to B to C to D.

It is not sufficient, however, to confine the analysis to individual routes. Even a cursory examination of the network pictured in Figure 2.1 indicates that a number (15) of the specific routes utilize the CD link. Thus, it is impossible to evaluate the capacity necessary over the CD link simply by measuring the traffic that moves from C to D or from D to C. It is also necessary to consider the need to move traffic from B to E, from A to F, etc. Thus, an accurate evaluation of U.S. rail capacity requires an examination of tens of thousands of potential routings over several thousand individual rail network links.[5]

[5] In fact the consideration of *every* possible routing over *every* possible link would generate millions and millions of distinct routes. The current analysis, however, restricts the potential number of routings to include only those routes over which traffic is observed. Thus, shipments from Cincinnati to New Orleans via Omaha are generally excluded from consideration.

Figure 2.1



2.2 THE DETERMINANTS OF LINK CAPACITY

The concept of link capacity encompasses both space and time. Specifically, link capacity is measured by counting the number of output units (freight cars, revenue tons, etc.) that can be moved over the network link in a specific time period (cars-per-day, tons-per-year, etc.).[6] The actual long-run ability of a link to accommodate traffic is determined by the characteristics of the traffic that uses the link, the physical characteristics of the link, and the ability of traffic to move on to and off of the link. Within the context of railroad transport, these determinants include (but are, by no means limited to) the direction and commodity mix of traffic, the configuration and quality of line-haul trackage, and the ability of terminal facilities to yard, switch, and dispatch trains.

2.2.1 *Traffic Mix and Line-Haul Characteristics.* The traffic moving between specific origin and destination pairs is a function of the vector of available transportation rates, the availability of spatial or commodity substitutes, and ultimately, the demand for downstream goods and services. Thus, while railroads can influence origin destination flows by manipulating rates, these flows are also subject to

largely exogenous forces. The same may or may not be true of actual routings. Again returning to Figure 2.1, a railroad that operates over this network may have to share control over the quantity of transportation demanded between A and F with a variety of other economic agents. It does, however, have considerable discretion over some portions of the actual routing of traffic between these points.[7] For example, if the railroad wishes to operate only westbound between C and A, A to F movements may be routed via B instead of utilizing the more direct ACDF route.

Differing traffic mixes require significantly different infrastructure configurations. Routes that handle largely one-way traffic obviously require fewer opportunities to meet opposing trains, so that sidings (passing tracks) or multiple main lines play a smaller role in determining capacity. Conversely, the capacity of routes that must accommodate two-way traffic (most routes) and particularly routes that see a

[6] Within some contexts, the discussion may focus on the length of time it takes to move a single output unit (carload, ton, etc.) over a specific link. Analytically, these approaches are identical.

[7] In advance of deregulation, routings were determined through the use of route tariffs published by the rail carriers. In the wake of deregulation, routings may be specified in contractual agreements. Again, however, it is the individual railroads that develop the set of options from which shippers may choose. The only real opportunity for shipper control of routings comes through the process of "Accounting Rule Eleven" moves wherein a shipper treats a movement over two separate railroads as two separate shipments.

diverse mix of traffic is heavily dependent on the number and spacing of sidings and/or availability of multiple main tracks.

Apart from link configuration, the physical characteristics and quality of the trackage depends both on the volume and mix of intended traffic. Routes that serve a high percentage of fast moving intermodal traffic may require super-elevated curves, greater clearances, and enhanced track quality for higher speed operations. Routes that primarily see bulk traffic movements may be particularly sensitive to grade. Ultimately, the weight of rail used, the anchoring and ballast system selected, the type and spacing of signals, decisions regarding grading and grade separations are all impacted by the mix of traffic that the trackage must accommodate. The variety of relationships between traffic mix and infrastructure requirements is expansive. Moreover, because the mix of traffic can change significantly over time and because the reconfiguration or modification of infrastructure is both time consuming and costly, the match between traffic mix and link characteristics may be less than pristine.[8]

[8] For example, as passenger traffic and routings declined, many railroads reduced the elevation in curves in order to reduce the rail wear associated with the operation of heavier slower-moving trains over track designed to accommodate high-speed passenger trains. However, just as many such projects were completed, the volume of intermodal shipments exploded. Intermodal trains are shorter and faster than the typical line-haul freight train, with characteristics that, in many ways, resemble passenger trains. Consequently, many carriers have found it desirable to reverse course and restore the elevated curves in some routes.

2.2.2 *Terminal Facilities*. Network nodes are formed where routes converge or diverge and where traffic can be interchanged from one network to another. In some cases these nodes and their associated functions require a minimal amount of infrastructure. At other locations, the origination, termination, interchange, and reorganization (blocking) of traffic requires acres and acres of facilities comprised of hundreds or even thousands of miles of trackage. The rate at which traffic can be passed along a network link is of little or no consequence if terminal facilities at the end of that link cannot receive the movement and dispatch it onto the next leg of its journey. Thus, terminal facilities of are of paramount importance in determining a route's capacity.[9]

This having been said, it must also be recognized that nearly every terminal facility of any size is characterized by a unique set of attributes that are the result of historical functions and relationships, topographical conditions, political bent, and sheer chance. Thus any attempt to model terminal

[9] One need only look at the UP's Houston operations or CSX's Queensgate Yard in Cincinnati to appreciate the impact that terminal congestion can have on route or even overall network capacity. Moreover, Chicago, the nation's largest rail hub, continues to produce myriad operating problems for the Class I, regional, and shortline carriers that move traffic within the region. See, "The Keys to Success," Traffic *World*, January 19, 1998, pp. 30-31.

operations is often, unproductive. Instead, any consideration of terminal congestion must be investigated on a case-by-case basis.[10]

2.2.3 *Deregulation and Railroad Mergers*. The pending transaction in which Norfolk Southern and CSX Transportation seek to acquire and divide Conrail assets represents only the latest step along a path of railroad consolidation that began after World War II. This pattern of consolidation has resulted in the movement of 70-80% of all rail traffic by only a handful of surviving Class I railroads. While shippers and policy makers continue to debate the competitive impacts of more recent mergers and acquisitions, from a functional standpoint, the pattern of rail mergers, combined with the pricing flexibility provided by deregulation has very probably led to a more efficient utilization railroad network capacity.

This potentially arguable conclusion rests on three closely related considerations. First, as the number of independent railroads is decreased, any routing flexibility retained by shippers is automatically reduced. Thus, consolidated railroads with a variety of routing options are freer to equalize traffic over

[10] In the simplest sense, a double track main with automatic block signals operated by the Burlington Northern in Oregon may be expected to have capacity characteristics that are, at least, similar to a like piece of trackage operated by Norfolk Southern in Alabama. Thus, the cross-sectional modeling described later in this document is possible. Alternatively, no two terminals are the same, so that cross-sectional comparisons would be of virtually no value.

their expanded rail network rather than engage in the capital expenditures necessary to increase the capacity of an isolated segment of track. A second and corollary consideration is the increased ability of merged carriers to run one-way traffic on a variety of network links. Thirdly, to the extent that a carrier wishes to specialize in the movement of specific commodities over specific routes it can simultaneously adjust the configuration or quality of its network links *and* adjust prices to reflect any cost advantages that its reconfigurations in the targeted line of business.

2.3 CARRIER INCENTIVES FOR CAPACITY EXPANSION

The report that details the first phase of this ongoing research considers the matter of long-run economic incentives in some detail. There are specific circumstances in which the economic incentives facing privately held rail carriers might result in something less than the optimal amount of railroad capacity. Specifically, the presence of market externalities or a lack of effective market competition could lead carriers to constrain long-run rail capacity below socially optimal levels. While these issues may or may not reflect areas of legitimate concern, it is our judgment that their consideration within the current analysis is inappropriate.

With regard to effective competition, the traditional Corps approach assumes that all relevant markets are effectively competitive in the long-run. The implications of relaxing this assumption extend far beyond the evaluation of capacity. From a pragmatic standpoint, the competitive assumption allows observed rates to form the basis of estimated long-run costs. As importantly, the economic theory that underpins the whole of benefit calculations is equally dependent on the presence of meaningful competition. If, in fact, there are rail markets where the level of competition is insufficient to produce optimal levels of investment, then those markets should be treated through the appropriate policy prescriptions. However, when evaluating long-run railroad capacity, any necessary remedies should be presumed to be successful so that the underlying assumption of effective competition is retained.

The case of externalities provides a similar circumstance. For the most part the externalities associated with surface freight transportation stem from environmental impacts that would not routinely be captured by the transaction in which transportation services are bought and sold. In a number of instances, extant environmental policies already work to internalize these external costs, so that no further consideration is called for. In those situations where corrective environmental measures are still needed,

they should be pursued. However, for the purpose at hand, it should be assumed that all necessary corrections have been (or will be) made.

SECTION 3

MODELING RAILROAD CAPACITY

3.1 LINE-HAUL VERSUS TERMINAL CAPACITY CONCERNS

The discussion in Section 2 alludes to the importance of terminal capacity as a determinant of overall route or system capacity. It is, nonetheless, our judgment that, with only a few exceptions, line-haul capacity should serve as the primary focus of the current investigation. This judgment is anchored in three observations: (1) export grain traffic that would divert to Pacific Northwest (PNW) destinations would impose little additional burden on rail terminal facilities in the Upper Mississippi region; (2) a measurable portion of the river-borne traffic considered in this study is already transported to or from the river by rail, so that much of the additional railroad tonnage already passes through affected rail terminal facilities; and (3) while diverted tonnages might represent significant increases in overall traffic for specific line-haul route segments, the magnitude of traffic diversions relative to the traffic already passing through terminals that gather and disperse rail traffic to and from numerous links is quite small. A full

characterization of projected traffic diversions and their impact on regional terminal facilities is provided in Section 4 along with exceptions to the judgment proffered above.

3.2 MODELING LINE-HAUL CAPACITY

The process for estimating and assessing railroad line-haul capacity is relatively straightforward. As noted above, there are many thousands of distinct route segments that vary considerably both in quality and in utilization. It is these variations that provide the basis for statistical estimation. The whole of the process can be characterized by the following three steps:

- Identify a cross-section of railroad route segments and collect information describing the physical characteristics of those route segments including the current level of traffic.
- Functionally relate observed traffic levels to route characteristics.
- Using the estimated relationships and the vector of current input prices to estimate the costs of incremental additions to railroad capacity.

3.2.1 *Route Links and Link Characteristics.* The development of Geographic Information Systems (GIS) technologies and coverages has greatly enhanced researchers' abilities to assemble link-specific

transportation data and it is four such coverages that provide the basis for the link characteristics used in this analysis.[11] These data were, in turn, modified to incorporate information gleaned from the U.S. Federal Railroad Administration Grade Crossing Inventory files and from other sources.

Initially, a set of roughly 2,500 distinct route segments were defined for use in this analysis. As noted above, a route segment or link for a particular railroad begins and ends at any point where traffic may converge or diverge. Additionally, link end points (or nodes) occur at any location where two railroads may legally interchange traffic. Once the study links were defined, information from four GIS coverages was mapped onto these links. Data from the Bureau of Transportation Statistics' (BTS) 1995 National Transportation Atlas Data (NTAD) 1:100,000 scale railroad network were combined with a newly released Federal Railroad Administration GIS coverage to provide the basic geographic information. These data were combined with data from the BTS 1996 NTAD 1:2,000,000 scale railroad network that contains information describing signaling and a measure of traffic density. The process of developing route characteristics from GIS data is described more fully in Appendix 1. The next step in the data development process involved using a preliminary grade crossing GIS coverage developed by

[11] Full documentation of dataset construction, including a description of GIS coverages and manipulations is available upon

Oak Ridge National Laboratories to locate the position of both separated and grade-level highway crossings. Next, data from the Federal Railroad Administration's Grade Crossing Inventory File were merged with the geographic data in order to provide additional information regarding train speeds, train frequencies and other operating characteristics.

The geographic units, referred to as arcs, are between a few tenths of a mile to several miles in length. However, the shortest route or study segment length is measured in miles and some route segments are several hundred miles in length. Consequently, each route segment generally consists of many arcs. It was, therefore, necessary to aggregate arc level data to conform to the route level unit of measure. This process is depicted in Figure 3.1. Missing data on some route segments precluded their use in any statistical application. Therefore, the final data set contains roughly 1,400 observations or route segments. The location and extent of their coverage is displayed in Figure 3.2. A full definition of all route level data used within the final model estimation analysis is contained in Table 3.1.

request.

Figure 3.1

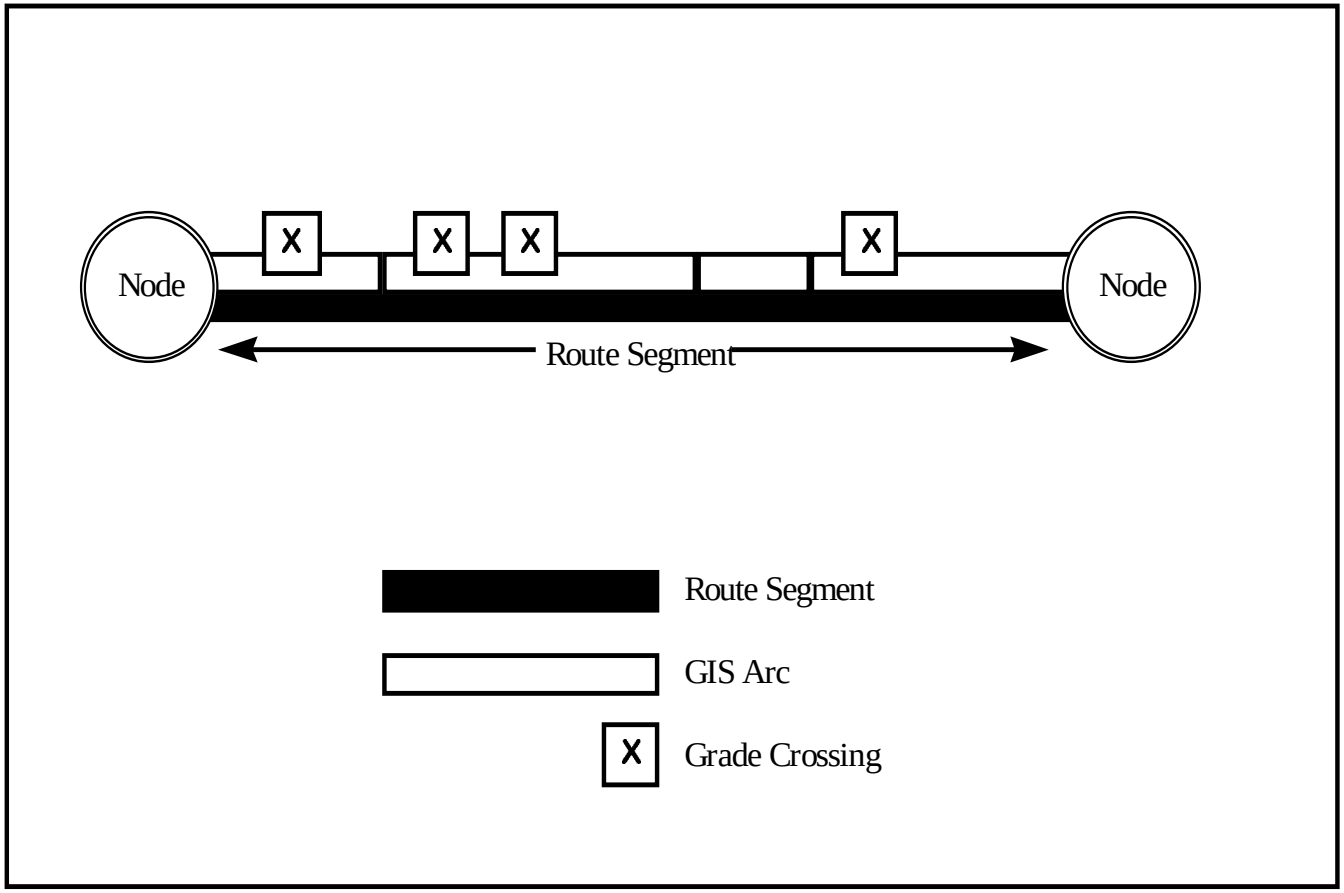
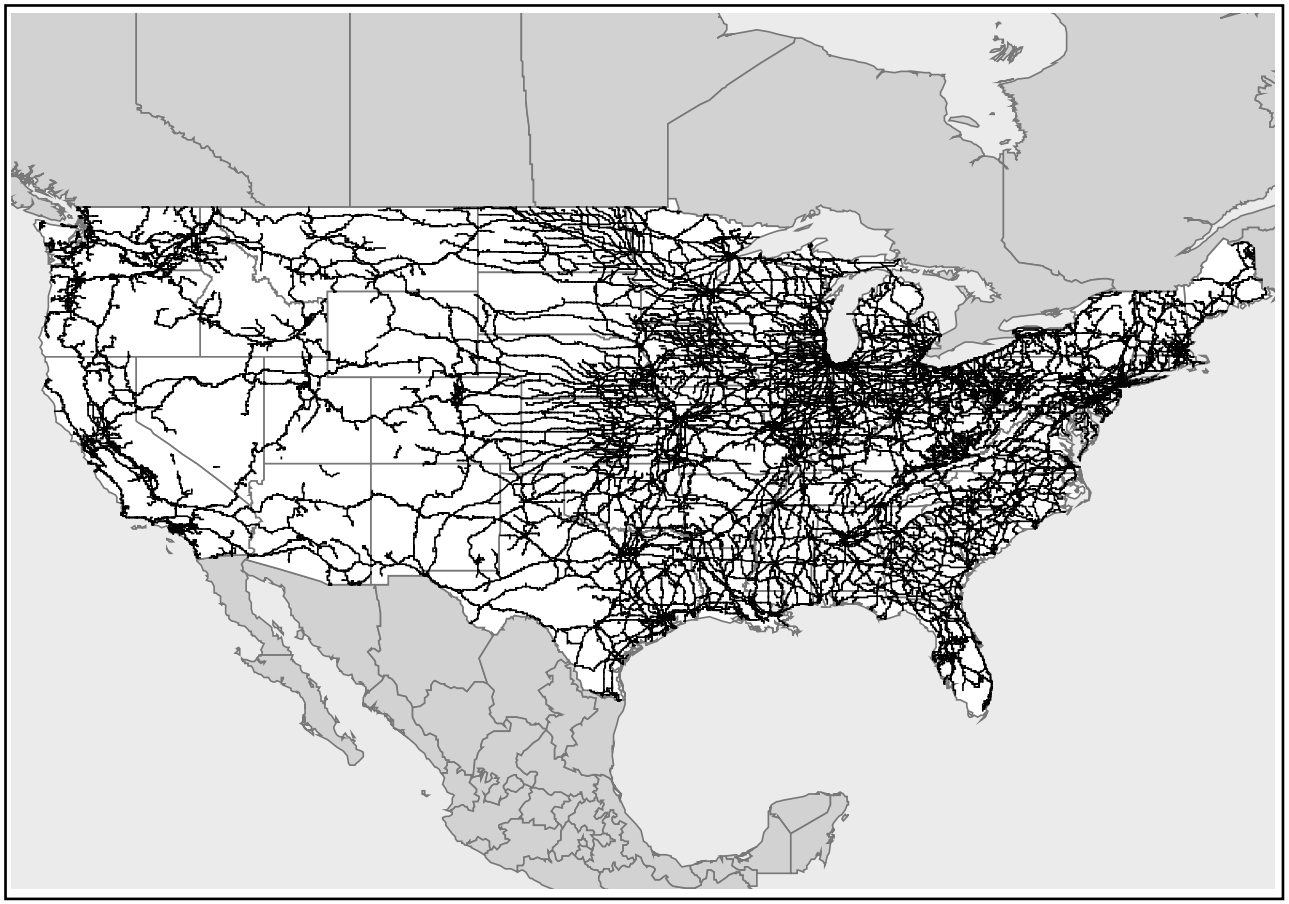

Node
Node
Route Segment
Route Segment
GIS Arc
Grade Crossing

Figure 3.2



3.2.2 Measuring Observed Traffic. At the center of this analysis is a fundamental assumption that the components of the rail network, as configured in 1994-95, were optimally suited to accommodate the traffic moved during that period. Thus, the traffic observed on each link during the study period stands as a measure of that link's capacity.

To measure the traffic over each link, the expanded movements from the Surface Transportation Board's annual Carload Waybill Sample were routed over the 1997 FRA 1:100,000 GIS network. A full description of the routing process is available in Appendix 2. However, several points are worth noting here. First, routings were based on actual origin, destination, participating carriers, and recorded points of interchange. Beyond these criteria, routes were selected on the basis of the shortest distance. This "short-line" criterion generally reflects railroad operating practices. This is not, however, true in every case. In order to assess the validity of the algorithm used in the routing process, model outputs for 89 of the 100 hundred most heavily used routes were compared with routings generated by an alternative method.[12] In 80 of the 89 cases, the TVA algorithm generated routes that were virtually identical to the

[12] The 1995 CWS contains nearly 500,000 records that reflect more than 75,000 routings. Except as noted in the GIS documentation, each of the geographic path of each of these unique routes was calculated for use in this analysis. The comparison routes were developed through the use of PC Rail, a software product produced by ALK Associates in Princeton, New Jersey.

paths generated with the alternative software. In 8 cases, there were significant variations reflecting cases in which railroads opt for a more circuitous routing and in one case, the TVA route varied from the actual routing because of a line sale. The sample of 100 was fully corrected and, because this sample represents between 15% and 20% of all rail traffic, we have complete confidence in a significant portion of the data. Moreover, the remaining rate of error appears to be within acceptable parameters. Once the CWS records were routed over the rail network, tonnage and car loadings were summed at the route link level to form measures of relative capacity

3.2.3 *Model Specification*. As discussed in Section 2, line-haul link capacity is a function of track configuration and the quality of track components, as well as exogenous factors including, but limited to topography (grade) and weather conditions. A number of model specification and functional forms were discussed with Corps personnel, independent transportation consultants, and other industry experts. Ultimately, the following model was selected.

$$
\begin{aligned}
MAXCARM_i = \beta_0 \; + \; & \beta_1(TIMETBLS_i) + \beta_2(CTCSPEED_i) + \beta_3(SPEEDRAT_i) + \\
& \beta_4(TRAINLEN_i) + \beta_5(MAINS_i) + \beta_6(CTCMAIN_i) + \beta_7(SIDSIZ_i) + \beta_8(SIDINGS_i) + \\
& \beta_9(SIDINT_i) + \beta_{10}(ABS_i) + \beta_{11}(CTC_i) + \beta_{12}(SWITCH_i) + \beta_{13}(SWITCH2_i) + \\
& \beta_{14}(ROUTLEN_i) + \\
& \beta_{15}(ROUTLN2_i) + \\
& \sum\gamma(CD_i) + \varepsilon_i
\end{aligned}
$$

Variable definitions are provided in Table 3.1

Table 3.1

Variable	*Description*
MAXCARM	The dependent variable is defined as the natural log of the number of gross carloads accommodated by the ith route link in the busiest 1995 calendar quarter. The log-linear specification was adopted to help capture any non-linear relationships between the dependent variable and explanatory variables. Gross carloads reflect the sum of revenue carloads and estimated empties.[13] The maximum quarterly value was selected to reflect seasonal variations in traffic levels and the assumption that infrastructure is constructed to accommodate the seasonal peak load.
TIMETBLS	Average timetable speed along the route link in question calculated by averaging the reported timetable speed at highway grade crossings. This variable is included as a measure of track component quality.[14]
CTCSPEED	The product of TIMETBLS and CTC, a measure of centralized traffic control described below. This interaction term is included to capture substitutability / complementarities between signal quality and track component quality [15]
SPEEDRAT	The ratio of the minimum train operating speed to the timetable speed included capturing variations in train speeds.

[13] Empty return ratios (ERRs) were based on a similar parameter used in cost calculations within the Rebee Rail Costing Model. Gross carloads equal (revenue carloads) x (1+ERR).

[14] As with most such analyses, there are innumerable data problems. In the case of timetable speed, the data reflect freight train speeds where no passenger service is operated, but reflect timetable passenger train speeds where passenger trains are present.

[15] For example the effect of timetable speed is reflected by the partial derivative of the model equation with respect to TIMETBLS. Normally, this would simply be the estimated coefficient for TIMETBLS, but because of the interaction term, the derivative includes is:

$$\frac{\partial \text{ MAXCARM}}{\partial \text{ TIMETBLS}} = \beta_1 + \beta_2(\text{CTC})$$

Variable	*Description*
TRAINLEN	The average train length observed along the network link calculated as the gross number of carloads divided by the total number of daily trains.
MAINS	The estimated proportion of mainline tracks within the route estimated by combing the number of mainline tracks at grade crossings throughout the link in question and the carrier-specific ratio of additional mainline miles to total route miles operated.
CTCMAIN	The product of CTC and MAINTRAK. This term is included to reflect substitutability or complementarity between signal quality and the amount of mainline trackage.
SIDSIZ	The average siding length along the route segment.
SIDINGS	Estimated proportion of sidings to mainline trackage based on the carrier specific ratio of sidings to mainline trackage and the number of "other" tracks observed at highway grade crossings along the specific route.
ABS	The percentage of the route link that is controlled by automatic block signals (ABS). ABS is assumed to be inferior to centralized traffic control (CTC), but superior to unsignaled or "dark" territory.
CTC	The percentage of the route link that is controlled by centralized traffic control (CTC).
SWITCH	The average number of daily switch movements along the link in question.
ROUTLEN	The route length as calculated from the GIS coverage. Because individual arcs were missing from some links, there are numerous instances in which the calculated route length is less than the actual length. This should not, however, affect the validity of the estimation results. To capture in additional non-linearities a quadratic term ROUTLEN2 is included in the specified model.
CD	Carrier intercept terms.[16]

3.3 ESTIMATION RESULTS

[16] A fully interactive model that included interactions between the carrier intercept terms and the other independent variables was tested, but rejected, as it offered no measurable improvement.

A full set of estimation results is provided in Table 3.2. On the whole, these results support the hypothesized link-specific correlation between observed rail traffic and those variables used to represent the quality and configuration of track structures. We must also conclude, however, that the general degree of model fit and the weak statistical significance of some variables suggests that factors other than track quality and configuration are also important determinants of the level of traffic observed on a particular route segment.

Based on the estimates, the greater train speeds that are facilitated by better track components appear to significantly improve the carload capacity of a network link, while variations in train speed reduce capacity. The coefficient estimates for CTC and ABS clearly indicate that the quality of signaling affects capacity and, as anticipated, the magnitude of CTC is considerably greater than that of ABS. Track capacity is negatively correlated with train length, indicating that, all else equal, it is more difficult to meet and manage trains of greater length. Coefficient estimates for the two interaction terms, CTCSPEED and CTCMAIN, were both negative and statistically significant. Moreover, their magnitudes, relative to

Table 3.2

Variable	*Coefficient Estimate*	*Standard Error*	*"t" (Parm=0)*	*Probability Parm=0*
INTERCEPT	8.289905	0.277913	29.829	0.0001
TIMETBLS	0.033229	0.002437	13.635	0.0001
CTCSPEED	-0.017	0.00365	-4.657	0.0001
SPEEDRAT	0.178289	0.09967	1.789	0.0739
TRAINLEN	-0.00091	6.66E-05	-13.614	0.0001
MAINS	0.7272	0.090022	8.078	0.0001
CTCMAIN	-0.41692	0.131276	-3.176	0.0015
SIDINGS	0.948858	2.394492	0.396	0.692
SIDSIZ	0.095958	0.024872	3.858	0.0001
ABS	0.430842	0.066326	6.496	0.0001
CTC	1.854777	0.177132	10.471	0.0001
SWITCH	0.113847	0.019442	5.856	0.0001
SWITCH2	-0.00517	0.001686	-3.064	0.0022
ROUTLEN	-0.00088	0.001075	-0.815	0.4155
ROUTLEN2	3.46E-06	5.17E-06	0.669	0.5036
CD076	CONFIDENTIAL[17]			
CD190				
CD712				
CD400				
CD555				
CD482				
CD721				
CD802				
Adjusted Model R^2 = 0.6012				

[17] Because confidential Waybill records were used to develop traffic volumes, carrier-specific estimation results are also held to be confidential.

estimates for the independent variables from which they are formed, supports the hypothesis that improved signaling increases capacity more when there are fewer mainline tracks or when train speeds are lower, but is a less effective means of adding capacity when multiple main tracks are present or when train speeds are already at relative high levels.[18] The coefficient estimates for SIDSIZ, and SIDINGS display the anticipated signs, although the magnitude and statistical significance of these estimates would, at first glance, appear to under-represent the importance of sidings as a means of adding link capacity.

3.4 INTERPRETING THE RESULTS

The estimation results as depicted in Table 3.2 are useful in evaluating the overall model performance. However, from the standpoint of assessing track capacity, a series of result applications may be more useful. Tables 3.3-5 illustrate the estimated relationship between independent variables and track capacity as measured by observed traffic under three different circumstances.

[18] While the interaction terms work to offset the individual coefficient estimates, the effects of additional mainline trackage or CTC are still positive. In every case the sum of the interaction terms and independent variables was statistically different from zero at a 95% level of confidence.

Table 3.3 illustrates the estimated track capacity for a 100 mile route segment of minimal quality. It is unsignaled, without sidings or additional main tracks, and suitable for train speeds of 20 m.p.h. or less. The estimation results suggest that trackage with this configuration and quality would support roughly five 40 car trains each day.[19] Based on consultation with industry experts, this estimated capacity appears reasonable.

Table 3.3

Variable/Value	*Measure*	*Variable/Value*	*Measure*
TIMETBLS	20	SIDSIZ	0
CTCSPEED	0	ABS	0
SPEEDRAT	1	CTC	0
TRAINLEN	40	SWITCH	0
MAINS	1	SWITCH2	0
CTCMAIN	0	ROUTLEN	100
SIDINGS	0	ROUTLEN2	10000
Estimated Capacity	17,514		
	5	Trains Per Day	

[19] Exponentiation of the intercept term reported in Table 3.5 suggests that nearly every piece of trackage, under any configuration and in any condition, will support one train a day.

Table 3.4 depicts the estimated capacity for a route segment based on the mean values of the independent variables. These data, therefore, depict an "average" route segment based on the sample of roughly 1,300 such segments. As would be expected this typical track segment reflects both better component quality and a more complex configuration. Consequently, it is estimated to accommodate nearly twice the number of daily trains and nearly four times as many cars as the trackage of minimal quality and configuration. Nonetheless, these results do reveal evidence that the data may not be entirely effective at measuring the intended variables. In particular the mean values for SIDINGS and SIDSIZ highlight the lack of specificity that is likely responsible for the rather lose model fit. It is impossible to discern whether these data reflect 14 equally sized (and very small) sidings or a much smaller number of more usable sidings.

Finally, Table 3.5 depicts a piece of trackage that is clearly superior to the sample mean. The route in this example is fully signaled with CTC, can accommodate 69 m.p.h. train speeds, and features a significant amount of secondary main, as well as a copious volume of passing track. This trackage is estimated to accommodate more than four times the number of daily trains and train cars hosted by the "average" track depicted in Table 3.7. Still, consultants, familiar with the industry, have suggested that

the trackage portrayed in Table 3.8 would, in fact, be able to accommodate a volume of traffic that significantly exceed the estimated 40 trains per day. Generally, it is our assessment that the estimation results systematically understate link capacity for higher quality route segments.

Table 3.4

Variable/Value	*Measure*	*Variable/Value*	*Measure*
TIMETBLS	38	SIDSIZ	0.321
CTCSPEED	14.858	ABS	0.161
SPEEDRAT	0.4848	CTC	0.391
TRAINLEN	79	SWITCH	1.970
MAINS	1.158	SWITCH2	3.881
CTCMAIN	0.452	ROUTLEN	41
SIDINGS	0.108	ROUTLEN2	1681
Estimated Capacity	64,226		
	9	Trains Per Day	

Table 3.5

Variable/Value	*Measure*	*Variable/Value*	*Measure*
TIMETBLS	69	SIDSIZ	5
CTCSPEED	69	ABS	0
SPEEDRAT	1	CTC	1
TRAINLEN	65	SWITCH	0
MAINS	1.2	SWITCH2	0
CTCMAIN	1.2	ROUTLEN	100
SIDINGS	0.2	ROUTLEN2	10000
Estimated Capacity	236,368		
	40	Trains Per Day	

SECTION 4

RAILROAD CAPACITY FOR UPPER MISSISSIPPI BASIN SHIPMENTS

The ultimate purpose of this research is to evaluate the extent to which diverted Mississippi River traffic would affect the need for and cost of railroad capacity for movements to, from, and within the Upper Mississippi basin. Armed with the estimation results developed in Section 3, predictions of diverted traffic, and rule-of-thumb measures of incremental track component and configuration costs, this section seeks to finally address the central focus of this study.

4.1 CAPACITY COSTS

The cost of building or modifying line-haul railroad trackage is, of course, a function of the quality and configuration of that trackage. It is also, however, affected by a wide array of exogenous factors. Specifically, soil conditions, terrain, environmental concerns, and the degree of urbanization can

all significantly impact the cost of a particular construction project. The challenge, within the current context, is to mitigate the effects of these specific factors in order to develop generic cost estimates that can be reasonably applied to a variety of potential infrastructure improvements.

Table 4.1 provides a summary of the generic or "rule of thumb" measures for costing the construction or modification of rail infrastructure developed by civil engineers the University of Tennessee's Transportation Center. Appendix 3 fully documents the methodology, data, and calculations used to produce these estimates. It should be noted, as well, that preliminary estimates were discussed with engineering professionals from a number of Class I railroads and with experts from private construction firms that are routinely engaged in rail project construction. It is, of course, possible to point to innumerable examples of rail infrastructure projects where the actual incurred costs are quite different than those contained within Table 4.1. We are, however, extremely confidant that the UT estimates are both reasonable and reliable.

Table 4.1 also contains the estimated necessary real rate of return on capital investments. Varying this rate, even modestly, has a significant impact on the final costs of multi-million dollar projects that span several decades. It is, therefore, important to carefully select this rate. To simplify the

estimation, the analysis ignores the potential impact of expected inflation, focussing instead on the *real* necessary rate of return. It is also important that the identified rate reflect the necessary return under conditions of competitive supply. Any observed impacts that result from the exercise of market power must be eliminated. The necessary rate of return should, instead, be a forward-looking, long-run, least-cost estimate of the cost of capital. Ultimately, after numerous machinations in consultation with a variety of sources, the current analysis settled on a real necessary rate of return of 8%. This figure, in combination with recent price patterns, yields nominal rates of return that are somewhat less than the benchmark rate established by the Surface Transportation Board for the assessment of revenue adequacy, but greater than the historical rates of return for most Class I carriers.

Returning to the expense of actually constructing or modifying trackage, the analysis assumes that siding construction varies from main-line construction both in the quality of track components and in their placement. For example, the calculation of siding costs incorporates the use of re-lay (used) rail. It also is based on tie spacing that is greater than those used to support mainline track. Light density trackage is of the construction typically found on long industrial tracks, small branch-lines, or

Table 4.1

Base Case				
Summary	Track $/Mile	Track $/Ft	Turnout cost	Control point cost
Siding Case	$383,730	$73	$98,768	$129,290
Light density case	$411,231	$78	333$92,768	$129,290
Medium density case	$457,013	$87	$98,768	$129,290
Heavy haul case	$489,841	$93	$119,691	$129,290
Variations in Terrain				
	Existing ROW	New ROW		
	Incr. $/Mile	$/Mile		
Flat Terrain		$119,262		
Rolling Terrain	$163,612	$786,241		
Mountainous Terrain	$546,532	$3,795,915		
Isolated Signal Projects[20]				
Signal Upgrades	$605,000			
Finance Costs				
Rate of Return	8%			

Class III railroad mainlines. This track classification is designed to handle modest tonnages at moderate speeds. The medium density case provides cost calculations for the type of trackage typically found on

[20] The University of Tennessee output did not specifically include isolated signal project costs. It did, however, contain data detailing the actual costs associated with a handful of such projects. TVA to develop the cost estimate used within the analysis used these figures.

Class I mainlines. This track will support moderate to heavy traffic at track speeds up to perhaps 60 m.p.h. Finally, the heavy haul case reflects the costs of constructing state-of-the-art trackage capable of handling continuously moving heavy traffic as might be evidenced in the Powder River region or within the northeast corridor. Here, rail weight is assumed to be, at least, 136 lbs., concrete ties are placed along with advanced anchoring systems, and ballast (and sub-ballast) levels are at their greatest.

The application of the UT cost estimates is reasonably straight forward. For example the construction of a one-mile long siding on existing right-of-way over flat terrain would include $383,730 for actual track construction, two turnouts at $98,768 each, and two control points (If CTC) at a cost of $129,290 per location for a total cost of $839,846. A signal upgrade from ABS to CTC over five miles of trackage would cost 5 x $605,000 or $3,025,000. Finally, the new construction of a 10 mile long second medium-haul main track through hilly terrain would cost $12,712,366 for earth work, track installation, turn-outs, control points and signals.

4.2 TRAFFIC DIVERSIONS AND ALTERNATIVE TRAFFIC FLOWS

The actual policy issue inherent in the Upper Mississippi basin is not so much whether extant river traffic will be lost to alternative modes, it is whether the projected growth in traffic will increase lock delays, thereby, increasing the costs incurred by current barge shippers and driving the preponderance of the increased traffic onto the railroads or highways, thereby altering the future costs of transport for railroads or highways. Thus, the phrase "diversion" is a bit misleading. Nonetheless, given that traffic growth on the Upper Mississippi River is forecast to be roughly 100%, a simple way to estimate the order of magnitude of this growth and its potential impact on other modes is to divert the entirety of current river traffic onto the existing highway and rail systems.

Table 4.2 contains a summary of projected traffic diversions for all non-crop commodities to alternative routings (either entirely by land or via a land/barge combination over the Port of St. Louis). [21]

For grain movements, it is again assumed that barge rates escalate to the point that navigation on the upper reaches of the Mississippi no longer provides a competitive transportation alternative. However, unlike non-grain commodities, a number of additional potential diversions are considered.

[21] These traffic diversions are developed specifically for application within the current analysis and may differ from the final

Table 4.2

Commodity	*Diversions to an All-Land Alternatives (in Tons)*	*Diversions to a Rail-Barge Alternatives Over St. Louis (in Tons)*
Coal	21,774,645	808,033
Petroleum Products	11,588,400	2,380,167
Chemicals	3,391,702	1,375,243
Fertilizers	4,233,323	989,819
WWIM, Ores, I&S Scrap, Slag	7,606,548	1,753,492
Stone, Sand, Cement	15,682,225	3,249,310
Processed Products	4,486,545	2,627,181
TOTAL	68,763,387	13,183,246

First, grain that is currently flowing over Louisiana Gulf destinations selects between an all rail routing to either a Louisiana or Texas export destinations or a rail/barge combination to a suitable Louisiana Gulf destination. Additionally, it is possible for export grain to divert to the Pacific Northwest (PNW). The actual diversion is based on the transportation rates developed within the NED analysis. Data describing these alternative flows are contained in Table 4.3. The quantities of traffic are projected graphically in

traffic diversions estimated within the traditional NED analysis.

Figure 4.1 where the width of the origin or destination pool reflects originating or terminating tonnages. A graphical representations of total inbound and outbound commodity flows is provided in Figure 4.1.

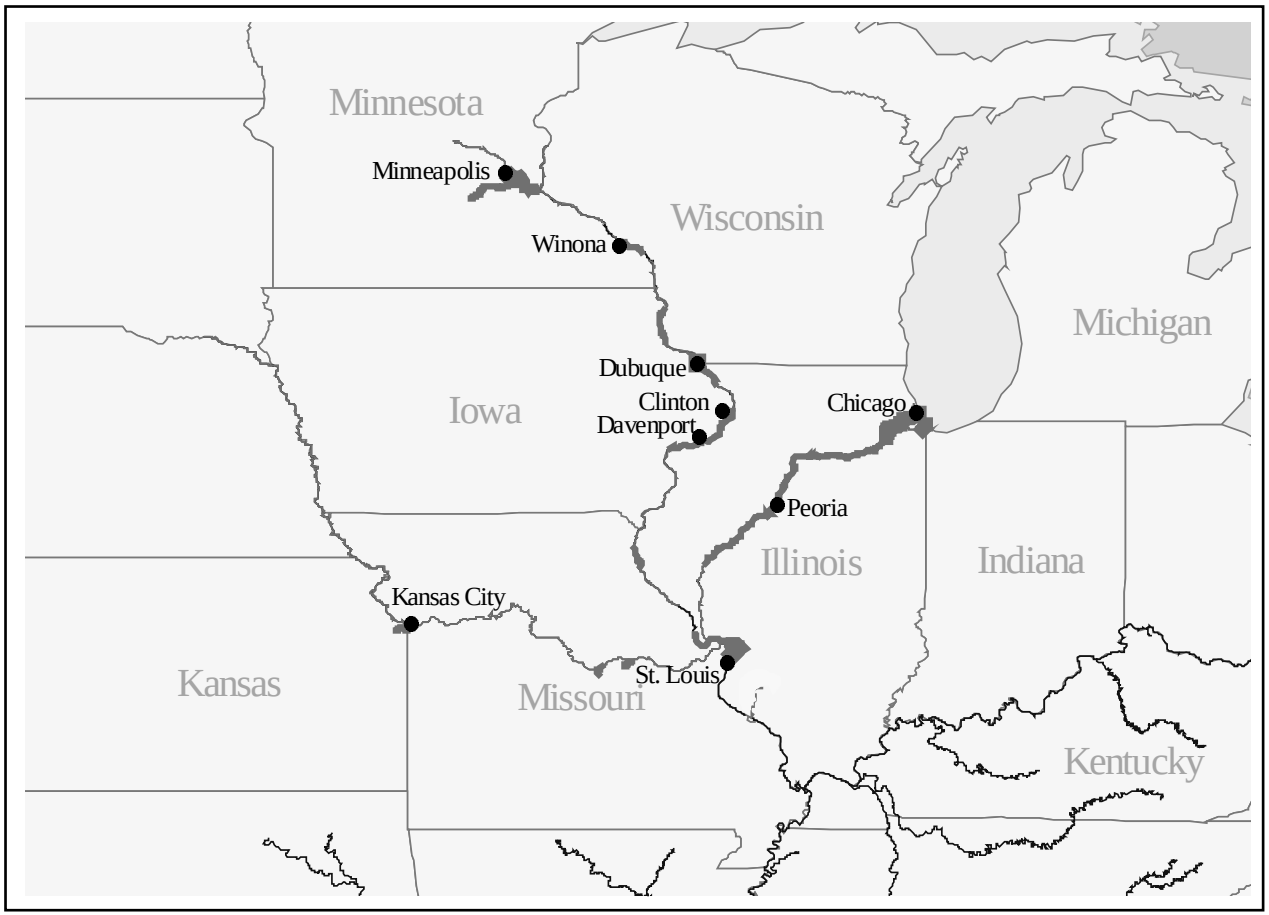
Table 4.3

Commodity	*Diversions to All-Land Alternatives (in Tons)*	*Diversions to a Rail-Barge Alternatives Over St. Louis (in Tons)*	*Diversions to Texas Gulf Alternatives (in Tons)*	*Diversions to the Pacific Northwest (in Tons)*
Corn	11,086,635	21,405,515	197,896	17,424
Soybeans	4,827,659	7,571,023	67,962	5,984
Wheat	2,741,581	2,409,297	279,104	440,256
Barley, Oats, and Sorghum	432,551	432,551	432,551	432,551
Total	19,088,426	31,818,386	977,514	896,215

Roughly one million tons of grain from western Iowa, western Minnesota and northeastern Nebraska would divert to the PNW and a similar amount of grain from southwestern Nebraska and eastern Kansas would move directly to Texas Gulf export locations. With these two exceptions, however, the vast majority of all commodity flows would remain in the Mississippi Valley. Moreover, given the amount of traffic that would rejoin the navigation system at St. Louis, it seems reasonably clear

that it is railroad capacity to and from (as well as, within) St. Louis that is most critical to the efficient diversion of Upper Mississippi traffic.

Figure 4.1



In the above figure the width of the various navigation pools reflects the relative activity as measure by 1995 originating and terminating tonnage.

4.3 LINE-HAUL CAPACITY AND CAPACITY COSTS

Given the above discussion, our examination of line-haul capacity costs is focused on the railroad route segments that connect the Upper Mississippi Valley with the St. Louis gateway. In the event that inland navigation cannot help to accommodate increased traffic, these rail route segments would be required to process considerably more traffic than they are currently configured to handle. Using the data developed thus far, we now turn to the task of estimating the cost remedying this capacity shortfall.

Ideally, it would be possible to divert every affected shipment onto the specific route predicted by current economics in order to precisely gage the incremental capacity necessary on every route-mile of track. However, both temporal and funding constraints preclude the possibility of such an analysis. Moreover, as recognized above, railroads now have more latitude than ever over actual routings, so that even the slightest future cost perturbation could make the currently predicted routings marginally inaccurate. As a second best approach, we elected to focus on a sample of 15 route segments that, together, comprise roughly 750 miles of the 5,000 miles of mainline trackage that connects the study region to the St. Louis area. These route segments and their characteristics are summarized in Table 4.4 below. The confidentiality of the waybill records used to develop carload estimates precludes the specific identification of these routes. However, these segments reflect trackage in Illinois, Iowa, Missouri, and

Wisconsin and represent properties operated by Burlington Northern - Santa Fe, Union Pacific (traditional), Union Pacific (C&NW), Norfolk-Southern and the Soo Line. Finally, without specific knowledge of the necessary incremental capacity, we proceed through the remainder of this analysis guided by the base-line goal of doubling currently observed capacity.

Appendix 4 contains incremental capacity cost calculations for each of the route segments depicted in Table 4.4. The similarities and contrasts revealed through a comparison of these calculations are very informative. First, it is clear that the circumstance in which it is easiest to increase capacity is one where the track in question is of modest construction, poorly maintained or otherwise configured in a way so as to provide only nominal current capacity. For example, consider the route segment identified as No. 12 in Table 4.4. Here, the average timetable train speed is only 16 m.p.h. and the ratio of minimum to timetable speed indicates that a number of trains operate at speeds well below the timetable average. At the same time, the presence of CTC suggests that this was once a route segment intended to accommodate a significant amount of trackage. In an attempt to increase the capacity of this route, we elected to completely overhaul it by installing entirely new medium capacity trackage on the existing right

Table 4.4

Route	*Timetable Speed*	*Minimum / Timetable Speed Ratio*	*Train Length (cars)*	*Number of Mainline Tracks*	*Proportion of Sidings*	*Siding Size*	*Proportion of ABS*	*Proportion of CTC*	*Daily Switch Movements*	*Route Length (miles)*	*Carloads Per Quarter*
1	17	0.26667	64	1.63	0.0991		0.6667	0.3333	0.00	10	47,019
2	64	0.00347	10	1.54	0.0991		0.9412	0.0588	0.00	81	170,826
3	44	1.00000	44	1.23	0.0991	0.210	0.0000	1.0000	0.00	18	101,688
4	33	0.44321	44	1.01	0.0991		0.0000	0.0000	0.06	112	29,199
5	46	0.03111	30	1.74	0.0991	1.613	0.9750	0.0250	2.91	112	165,761
6	59	0.55682	31	2.03	0.1113		0.0000	0.0000	0.00	25	143,544
7	32	0.38450	391	0.87	0.1113		1.0000	0.0000	0.02	33	27,775
8	29	0.31925	9	1.16	0.1113		0.0000	0.0000	0.92	31	30,638
9	29	0.24576	59	1.05	0.1113		0.0000	0.0000	0.28	40	24,258
10	45	0.49551	65	1.42	0.1113		0.0000	0.0000	1.74	8	67,010
11	27	0.34560	18	0.92	0.1280	0.390	0.0000	0.0000	0.97	46	20,197
12	16	0.25597	48	0.38	0.0771	2.920	0.0000	0.8000	2.12	29	39,628
13	19	0.21621	141	0.88	0.0771	0.600	0.0000	0.0000	2.20	91	14,379
14	54	0.62957	23	1.20	0.1241	0.410	0.0000	1.0000	2.78	58	161,393
15	40	0.52895	144	0.96	0.1241		0.0000	1.0000	0.26	79	78,151
Mean	37	0.38151	75	1.20	0.1055	1.024	0.2389	0.2811	0.95	52	54,555

of way, adding two, 10,000 foot sidings, and completing the CTC over the entirety of the route. The costs of these measures would be significant - nearly $22 million in total. However, these expenditures also would purchase a significant increase in annual capacity. Absent the rehabilitation, in its current condition, the route segment can accommodate roughly 160,000 car movements per year. After the track replacement, signal improvements, and siding construction described above, the same route segment is

estimated to accommodate more than 375,000 car movements per year. Even assuming a 100% empty return ratio (ERR), the rehabilitated route segment could be used provide over 300 million ton-miles of transportation services. If we assume that, on average, the components of this upgrade will have a productive life of 30 years, then the cost of the incremental track capacity is estimated to be 0.64 cents per ton-mile. A route description and incremental calculations are provided in Table 4.5.

While the calculations described above are all that is necessary to facilitate the comparison of incremental rail costs and incremental barge costs, they do not answer the concerns of most shippers. From the standpoint of shippers, the 0.64 cents per ton-mile incremental capacity cost is only relevant when viewed in comparison to the capacity costs currently embedded in observed railroad rates. If the incremental cost exceeds current capacity costs, the future average will increase; so that cost-based rates would also be forced to increase. Alternatively, if the incremental cost of the capacity necessary to accommodate increased demand is less than the capacity costs currently embodied within rates, then the future average capacity cost would be lowered and competitively determined rates would decline. While a formal comparison of these costs is beyond the scope of the current research, an arms' length

Table 4.5

Route and Route Characteristics	
State of Operation	Illinois / Iowa
Average Timetable Speed	16.28
Siding Size	2.92
Percent ABS	0
Percent CTC	0.8
Route Length	28.88
Daily Switch Movements	2.11829
Average Train Length	48.119
Train Speed Ratio (Minimum / Timetable	0.25597
Number of Mainline Tracks	0.38129
Proportion of Trackage with Sidings	0.07711
Carloads Per-Year Supported	158,512
Infrastructure Improvement and Costs	
Rebuild Track to Medium Density Standards	17,923,650
Install (2) 10,000' Sidings	1,855,072
Upgrade Remaining Track Signals to CTC	3,978,480
Finance Cost	$35,953,496
TOTAL	57,855,626
Incremental Capacity Improvement	
In Carloads Per-Year	218,514
Percentage of Original	237.85%
In Ton-Miles (100% ERR)	302,912,747
Incremental Per-Ton-Mile Capacity Cost	$0.00637

examination suggests that the incremental cost of additional capacity along this route is unlikely to adversely affect competitively determined rates. Using 4.5 cents per ton-mile as a ball-park rate, traditional rail costing models would assume that roughly two-thirds of this rate is attributable to variable costs, while the remaining 1.5 cents per ton-mile is a necessary contribution toward fixed costs.[22] Determining the precise proportion of that penny and one-half that accounts for the historical cost of line-haul capacity would constitute and arduous (and very probably contentious) accounting exercise. Nevertheless, the 0.64 cents incremental capacity cost does not, at a glance, appear to threaten markedly higher railroad rates.[23]

It is one thing to indicate that a poorly constructed or maintained piece of trackage could be rehabilitated to provide cost-effective new capacity, but what of those cases where the infrastructure is already of a high caliber? The route numbered 14 in Table 4.4 provides an ideal opportunity to examine

[22] While 4.5 cents per ton-mile reflects a men rate across all commodities in all markets, it is not uncommon to observe grain rates that are as low as 1.8 cents per ton-mile or rates for the movement of coal that are in the range of 1.2 cents. Thus, even considering that variable costs for unit train movements of dry bulk commodities are lower than for other movements, it is still apparent that the current methodology provides only a rough approximation of the fixed cost of providing line-haul trackage.

[23] It is important to recall that the Corps' Principles and Guidelines call for the assumption of adequate capacity unless there is compelling evidence to the contrary.

the incremental capacity costs associated with expanding the capacity of an already well functioning rail route. In contrast to the first example, average timetable train speeds are at nearly 55 m.p.h. and the variability of observed train speeds is considerably lower. The route is already fully signaled with CTC and there would seem to be few options for increasing route capacity. This route segment typifies the upper end of the medium-haul case described in the UT cost calculations.

The calculations detailed in Table 4.5 reflect our attempt to transform this route segment into a premium heavy-haul line. Existing trackage is supplemented with the addition of a second 58 mile mainline constructed to heavy-haul standards and two additional 10,000 foot sidings. Additionally, it is assumed that 25% of the new second main must be constructed on newly acquired right of way, so that the per-mile construction cost escalates to $809,110 per mile.[24] The total cost of this rehabilitation is in excess of $145 million. However, as Table 4.5 indicates the incremental increase in line-haul capacity is estimated to be more than one billion ton-miles per year. Again, assuming a thirty year asset life, the cost of this incremental capacity is estimated to be 0.43 cents per ton-mile, or somewhat less than the incremental cost in the first example.

Table 4.5

Route Characteristics	
State of Operation	Missouri
Average Timetable Speed	54.35
Siding Size	0.41
Percent ABS	0
Percent CTC	1
Route Length	58.472
Daily Switch Movements	2.11829
Average Train Length	23.092
Train Speed Ratio (Minimum / Timetable	0.62957
Number of Mainline Tracks	1.2021
Proportion of Trackage with Sidings	0.12409
Carloads Per-Year Supported	524,729
Infrastructure Improvements And Costs	
Construct 2nd Main Track to Heavy-Haul Standards	$53,099,008
Install (2) 10,000' Sidings	$1,855,072
Finance Costs	$90,210,006
TOTAL	$145,164,085
Incremental Capacity Improvement	
In Carloads Per-Year	397,928
Percentage of Original	175.83%
In Ton-Miles (100% ERR)	1,116,847,116
Incremental Per-Ton-Mile Capacity Cost	0.0043

[24] As with virtually all examples developed in this investigation, it is assumed that the terrain is rolling rather than flat or

Table 4.6 summarizes the incremental cost calculations for each of the 15 sample route segments. On average, under a variety of different scenarios, involving many different carriers, in at least four Upper Mississippi basin states, the incremental cost of an additional ton-mile of line-haul capacity is estimated to be 0.395 cents. These estimates clearly indicate that if necessary, Class I rail carriers can add the appropriate volume of new line-haul capacity at a cost, which is very unlikely to prove harmful to the overall level of competitively, determined rail rates.

4.4 TERMINAL CAPACITY

A diversion of Upper Mississippi river traffic to the rail network would increase traffic levels in a number of terminals throughout the region. Specifically, the Twin Cities, Chicago, Omaha/Council Bluffs, Lincoln, Kansas City, and Houston would all see additional rail traffic. At these locations, however, the incremental increase in rail traffic could be measured in carloads per-day. Consequently, an exhaustive study of whether or not sufficient capacity exists seems unwarranted. By comparison, rail traffic within the St. Louis area would increase precipitously both because of the additional traffic that

mountainous. Refer to Appendix 3 for a description of these terrain conditions.

Table 4.6

Example Number	*Carloads Per-Year Supported (x 1,000)*	*Infrastructure Improvement Cost (x 1,000)*	*Finance Costs (x1,000)*	*Total Incremental Capacity Cost (x 1,000)*	*Incremental Capacity Carloads Per-Year (x 1,000)*	*Percentage of Original*	*In Ton-Miles (100% ERR), (x 1,000)*	*Incremental Per-Ton-Mile Capacity Cost*
1	188	$1,803	$2,960	$4,763	116	161.53%	28,216	$0.00563
2	683	$22,869	$37,541	$60,410	254	137.10%	491,722	$0.00410
3	407	$8,649	$14,198	$22,848	110	127.04%	47,693	$0.01597
4	117	$67,808	$111,475	$179,284	277	337.22%	745,236	$0.00802
5	663	$18,017	$29,576	$47,592	139	120.99%	373,852	$0.00424
6	574	$15,246	$25,027	$40,273	309	153.86%	187,016	$0.00718
7	111	$21,548	$35,224	$56,772	95	185.54%	148,471	$0.01275
8	123	$20,489	$33,634	$54,123	209	270.23%	308,423	$0.00585
9	97	$26,880	$44,125	$71,004	186	291.23%	354,738	$0.00667
10	268	$1,053	$1,729	$2,782	177	165.88%	70,857	$0.00131
11	81	$30,897	$50,719	$81,616	170	311.04%	380,282	$0.00715
12	159	$21,902	$35,953	$57,856	219	237.85%	302,913	$0.00637
13	58	$112,059	$183,951	$296,009	237	511.92%	1,039,679	$0.00949
14	525	$54,954	$90,210	$145,164	398	175.83%	1,116,847	$0.00433
15	313	$74,595	$122,452	$197,047	324	203.52%	1,228,304	$0.00535
Mean	291	$33,251	$54,585	$87,836	215	226.05%	454,950	$0.00644

would originate or terminate there and because of the incremental increase in northbound and southbound movements that would simply pass through the area. If we assume that all downbound grain, except for the small amount diverting to Texas or the PNW, would pass through the St. Louis area and consider the

volume of other commodities that would move to or from the area as a part of a multi-modal movement, the additional rail tonnage within the St. Louis area could amount to as much as 65 million tons a year. Moreover, nearly half of that tonnage would be grain destined for transloading to barge at St. Louis. The impact of both the general increase in traffic and the specific increase in grain transloadings seem worthy of investigation.

Table 4.7 provides a summary of 1996 rail traffic that either originated or terminated in the St. Louis Bureau of Economic Analysis (BEA) area. In addition to this traffic, waybill statistics indicate that another 20 million tons were interchanged between carriers in the area. Finally, an application of the routing algorithm described in Section 3 suggests that perhaps another 20 million tons of railroad traffic passed through the area on a single carrier, destined for some other location.[25] In total, it appears that, in 1996, the railroad infrastructure in and around St. Louis handled roughly 100 million tons of revenue traffic (or approximately 5% of the U.S. total). Clearly, any situation that places an additional 30-60 million tons of traffic at this terminal location could necessitate the addition of new capacity.

Table 4.7

Two Digit Standard Transportation Commodity Code	*1996 Tons Originating or Terminating in the St. Louis BEA Area*	*Two Digit Standard Transportation Commodity Code*	*1996 Tons Originating or Terminating in the St. Louis BEA Area*
1	16,186,418	32	1,655,274
9	920	33	650,100
10	3,960	34	33,096
11	24,735,538	35	3,380
14	1,597,760	36	49,352
20	3,620,256	37	801,651
21	3,000	38	800
22	1,720	39	3,800
23	1,680	40	804,266
24	2,136,168	41	18,320
25	8,440	42	103,440
26	1,495,316	43	15,200
27	13,760	44	32,560
28	5,125,469	45	31,760
29	1,497,498	46	1,978,240
30	4,080	48	53,240
TOTAL - ALL COMMODITIES			62,666,462

[25] It is also possible that some portion of the 62 million tons originating and terminating in St. Louis were actually interchange movements where separate waybills were prepared under Accounting Rule 11.

While a 30-60% increase in traffic volume would tax the entirety of the regional infrastructure, the two elements that are currently blamed most often for congestion problems include the capacity of the two railroad bridges that span the Mississippi River at St. Louis and the ability of the Terminal Railroad Association of St. Louis (TRRA) to expeditiously interchange traffic between carriers. Thus, the extent to which diverted traffic might cause significant congestion or necessitate costly infrastructure modifications is very much a function of whether that diverted traffic would be required to cross the Mississippi at St. Louis and whether or not it would require interchange.

Apart from general issues of rail capacity, the above discussion makes it clear that it would be necessary to transload an additional 30 million tons of grain from rail to barge each year. Waterborne commerce records indicate that roughly 10 million tons of grain are loaded to barge on the reaches of the Mississippi below Lock and Dam 26 and above Cairo, Illinois, with the vast majority of this being loaded in or around the St. Louis area. Thus, the diversions based on current economic conditions would require a tripling of barge loading capacity within the region.

Three important points may serve to mitigate the import of the above discussion. First, as noted in Section 2, the continuing pattern of railroad consolidations provides rail carriers with considerably

more latitude in developing routing alternatives that bypass congested terminal facilities. Consequently, while current practices indicate a significant increase in terminal activity in and around St. Louis if navigation cannot economically accept its share of new traffic, it may be possible for a measurable portion of traffic to be routed so as to avoid St. Louis. Next, an examination of the transportation rates that serve as the basis for diversion calculations reveals that the benefit to St. Louis rail/barge routing as compared to an all-land movement is very often marginal. That is to say that a very small increase in the cost of moving traffic over St. Louis, may lead to an all-land diversion that need not include St. Louis in the routing. For example, even a modest increase in the cost of the St. Louis rail/barge alternative would could divert export corn movements toward Kansas City and a Texas Gulf export destination. Finally, policy-makers must realize that a doubling of output growth will necessitate both private and public expenditures on new capacity. The question is not *whether* money will be spent, but is instead *where* the additional expenditures will provide the most efficient transportation. Even considering these caveats and qualifications, however, it is clear that the availability of railroad capacity in and around St. Louis is an area of concern.

SECTION 5

CONCLUSIONS AND SUMMARY COMMENTS

Those familiar with the empirical data and methods commonly used in transportation economics are sure to conclude that the above analysis pushes the available data to the limits of their usefulness and, simultaneously, employs myriad simplifying assumptions that are routinely violated within the day-to-day world of transportation. The ambitious nature of this investigation combined with the paucity of useful information simply demanded that we be both inventive in our approach and accepting of a certain level of imprecision. Thus, the conclusions we draw from this study rest on a relatively fragile analysis. However, noting this qualification, we remain convinced that both the methods and results reported above represent the best generalized treatment of railroad capacity currently available. Moreover, we are sufficiently confident in the empirical results to urge their incorporation into the more traditional economic analyses that are being conducted with respect to Upper Mississippi River navigation.

The transportation infrastructure that is the focus of more broadly framed policy questions is the product of a remarkably dynamic and resilient spatial equilibrium in which producers, transportation

providers, and downstream consumers continually modify their behaviors to reflect changing market conditions. Thus, any number of exogenous changes could disrupt the interrelated predictions that form the basis for this rail capacity analysis. If, however, future events and market outcomes unfold in ways that are not radically different from those foreseen at the present time, then the analysis presented above, in combination with other work on the Upper Mississippi, supports the following conclusions:

- Input usage and output growth in the Upper Mississippi basin will necessitate the addition of new transportation capacity over the coming decades.

- Given the current capacity embodied within the Upper Mississippi navigation system, as well as the observed set of operating practices, the evolving incremental increases in transportation demand will place considerable levels of new traffic on the nation's interior rail system.

- In most cases, the line-haul segments that, together, form the routes over which expanded traffic flows must be accommodated can be modified to do so without placing an undesirable upward pressure on competitively developed railroad rates.

- At least in the case of the Upper Mississippi basin, concerns regarding terminal congestion and the adverse effects this congestion may have on railroad pricing should be limited to operations in and around St. Louis.

- With the possible exception of movements to, from and through St. Louis, the traditional Corps assumption of ample alternative modal capacity is valid for use in the analysis of Upper Mississippi navigation.

In order that there be no confusion, we wish to explicitly note that these results *do not* imply that Upper Mississippi River navigation is without economic benefit. They do, however, support the traditional methods by which national economic development benefits are calculated. The Corps' Principles and Guidelines explicitly instruct analysts to assume sufficient modal capacity unless there is compelling evidence to the contrary. The results of the current analysis do not constitute such evidence.

GIS PROCESS OVERVIEW
for the
RAILROAD LINE-HAUL CAPACITY PROJECT

Geographic Information Systems Group
Engineering Services
Tennessee Valley Authority
Norris, Tennessee

May 1997

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LIST OF ABBREVIATIONS

AML - Arc Macro Language

BTS - Bureau of Transportation Statistics

DEM - Digital Elevation Model

FRA - Federal Railroad Administration

FTP - File Transfer Protocol

GIS - Geographic Information System

NTAD - National Transportation Atlas Databases

ORNL - Oak Ridge National Laboratory

USGS - United States Geological Survey

INTRODUCTION

Members of the TVA Norris GIS Group accepted a project from the TVA Navigation Team in February 1997 to assist them in determining the line haul capacity of selected railroad lines in the United States. The objective of the GIS phase of the project was to merge *attribute* information from multiple transportation and topographic data sources. This was a pilot project to be accomplished in the least amount of time and finances possible — not to provide a topologically correct routing network.

The primary attributes requested by the customer were:

- specialized route identification numbers
- railroad ownership names / abbreviations
- USGS Digital Line Graph major and minor attribute codes
- density categories
- signaling system types
- slope information
- railroad grade crossing identification numbers and street names

A specialized route identification number was manually added by an undergraduate student interning with the TVA Navigation Team. The railroad ownership names and major and minor attribute codes were taken from a 1:100,000 scale railroad network provided by the Bureau of Transportation Statistics. The density and signaling information was taken from a 1:2,000,000 scale railroad network also provided by BTS. Slope information was calculated from USGS Digital Elevation Model data. Railroad grade crossing data were acquired from the Oak Ridge National Laboratory.

Because of the lack of common attribute information (no key fields), it was necessary to use a Geographic Information System to *spatially* join each database together. For instance, the 1:2,000,000 scale network arc attributes were joined to the 1:100,000 scale network arc attributes based on their proximity. Figure 1 and Tables 1, 2, and 3 illustrate the process of joining an arc from the 1:2,000,000 scale network to an arc from the 1:100,000 scale network. An example arc (Arc #1) from the 1:100,000 scale network is shown in Figure 1 and its attributes in Table 1. An example arc (Arc #99) from the 1:2,000,000 scale network is also shown in Figure 1 and its attributes are depicted in Table 2. In this example, Arc #99 is the arc nearest to Arc #1, therefore its attributes are appended to the Arc #1 attributes. The resulting attribute table is shown in Table 3.

Members of the GIS Group used this type of process to merge all of the initial databases together to produce the final output for the project (Figure 2). The GIS Group used Arc / Info® 7.0.4 and ArcView® 2.1 running on a network of Sun Ultra Workstations. The final digital data files were transferred to the customer on a network Pentium PC.

Unlike most GIS tasks, the final products of this pilot project were listings of attribute information only. In most GIS transportation applications, the primary objective is to produce a topologically correct network at a maintained scale. In this case, the emphasis was not on the connectivity of the geographic data, but on the amount of time taken to merge the attribute

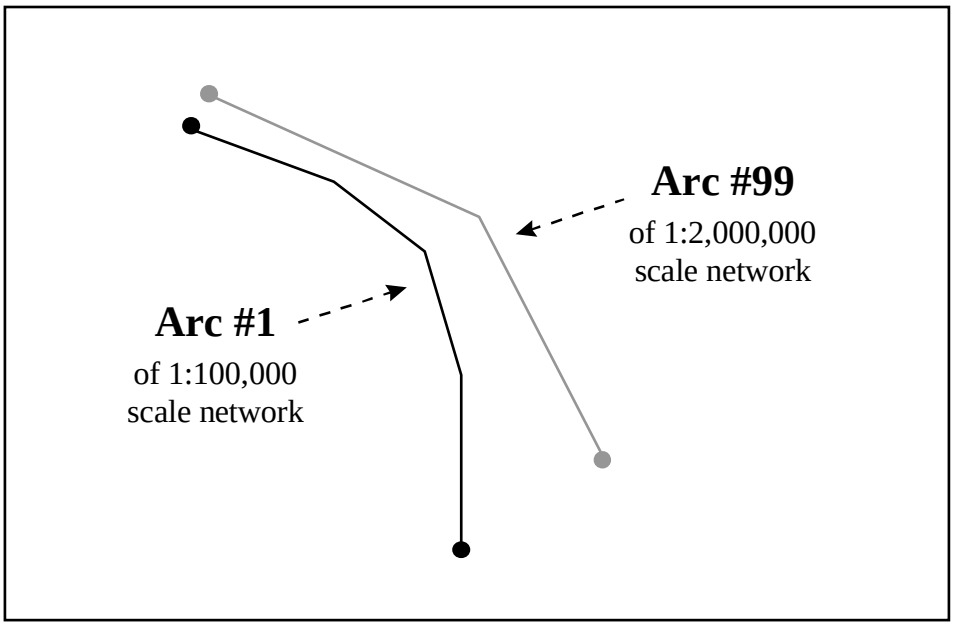

Figure 1. Spatail Join Example

Arc100k #	Route #	Owner	Major Code	Minor Code
1	2462	WC	180	208

Table 1. Example 1:100,000 Scale Railroad Network Attributes

Arc2m #	Density	Signaling
99	1.0	Manual

Table 2. Example 1:2,000,000 Scale Railroad Network Attributes

Arc100k #	Route #	Owner	Major Code	Minor Code	Arc2m #	Density	Signaling
1	2462	WC	180	208	99	1.0	Manual

Table 3. Resulting Railroad Join Attributes

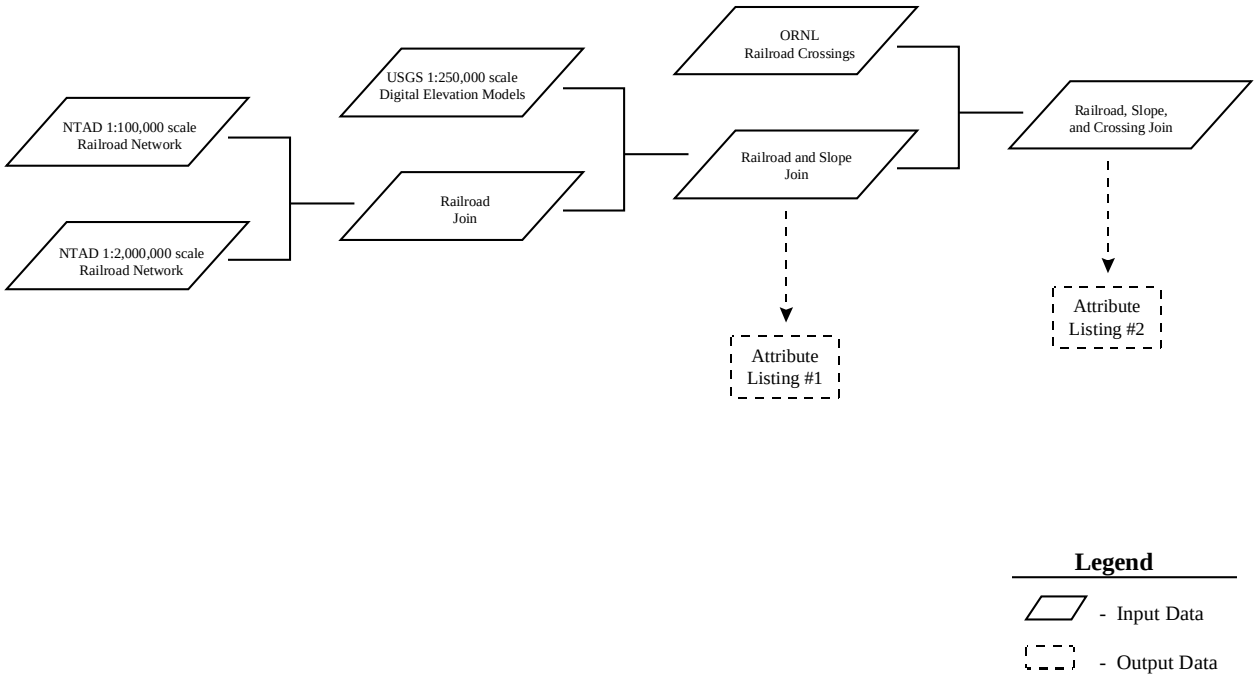

Figure 2. Multiple Joining of Input Data to Produce the Final Output Data

information together. Therefore, although the 1:100,000 scale railroad network did not maintain connectivity, it was chosen as the base network for the project since the 1:2,000,000 scale network did not contain secondary routes. For the next phase of the project, however, a topologically correct 1:100,000 scale railroad network should be available.

INPUT DATA

There were four main input data sets used for the project:

1). 1:100,000 scale railroad network taken from the 1995 National Transportation Atlas Databases (NTAD) compact disc. The CD was ordered via the Department of Transportation's Bureau of Transportation Statistics website: **http://www.bts.gov**
C code and ARC Macro Language (AML) routines were written to import the data into Arc/Info®.

2). 1:2,000,000 scale railroad network taken from the 1996 National Transportation Atlas Databases (NTAD) compact disc. The CD was ordered via the Department of Transportation's Bureau of Transportation Statistics website: **http://www.bts.gov**
The data was imported into Arc/Info® using an AML macro downloaded from the internet (btsarc.aml) and a user written AML macro routine.

3). 1:250,000 Digital Elevation Models downloaded from the United States Geological Survey website: **http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/index1m.html**
The DEMs were downloaded from the internet and copied to recordable compact disks. Another set of CDs was also made which contained only those DEMs thought to be necessary for the project. AML macros were written to copy each of these DEMs from CD to a disk drive, uncompress them, and use the Arc/Info® DEMLATTICE command to convert them to an Arc/Info® LATTICE.

4). Railroad grade crossing data received from Bruce Peterson of the Oak Ridge National Laboratory via FTP. The railroad crossing data were imported into Arc/Info® manually using Info™ commands.

In addition, the Navigation Team student used an Arc/Info® coverage of the 1995 NTAD Place Names provided by the Norris GIS Group, and a list of railroad routes along with a PC Rail© network provided by the customer.

PROCESS OVERVIEW

A simplified graphical description of the GIS process is shown in Figure 3. Crucial network routes were first extracted from the NTAD 1:100,000 scale network to create a new, reduced network. Attributes from the NTAD 1:2,000,000 scale network were then joined to the new 'crucial route network'. Slope attributes were calculated for each arc in the new network and an output listing was created which contained all attribute information for every arc. Afterwards, the network arc attributes were joined to the railroad crossing point attributes and another output listing was created. Both output listings were then delivered to the customer.

Selecting Crucial Routes

A list of crucial railroad routes was defined and provided by the customer along with a PC Rail© railroad network to the Navigation Team undergraduate intern. For each route on the list provided, the intern used the origin, destination, and ownership names to visually locate the route on the PC Rail© network on a desktop PC. A Sun workstation running Arc/Info® was used to visually locate the identical route on the 1:100,000 scale network. The arcs for the route were <u>select</u>ed[1] in ArcEdit and <u>put</u> into (appended to) a new data layer. A unique identification number was manually assigned to each route via the listing received from the customer. The final Arc/Info® output coverage containing the crucial routes was then given to the Norris GIS Group. Because of some of the following problems, not all routes were matched.

1. The two networks were not displayed in the same projection. The 1:100,000 scale network was in a Geographic coordinate system (latitude and longitude in decimal degrees) and the PC Rail© network projection was unknown.
2. There were discrepancies amongst railroad ownership names.
3. The topology differed between the two networks.

[1] Arc/Info® commands are underlined

GIS PROCESS OVERVIEW

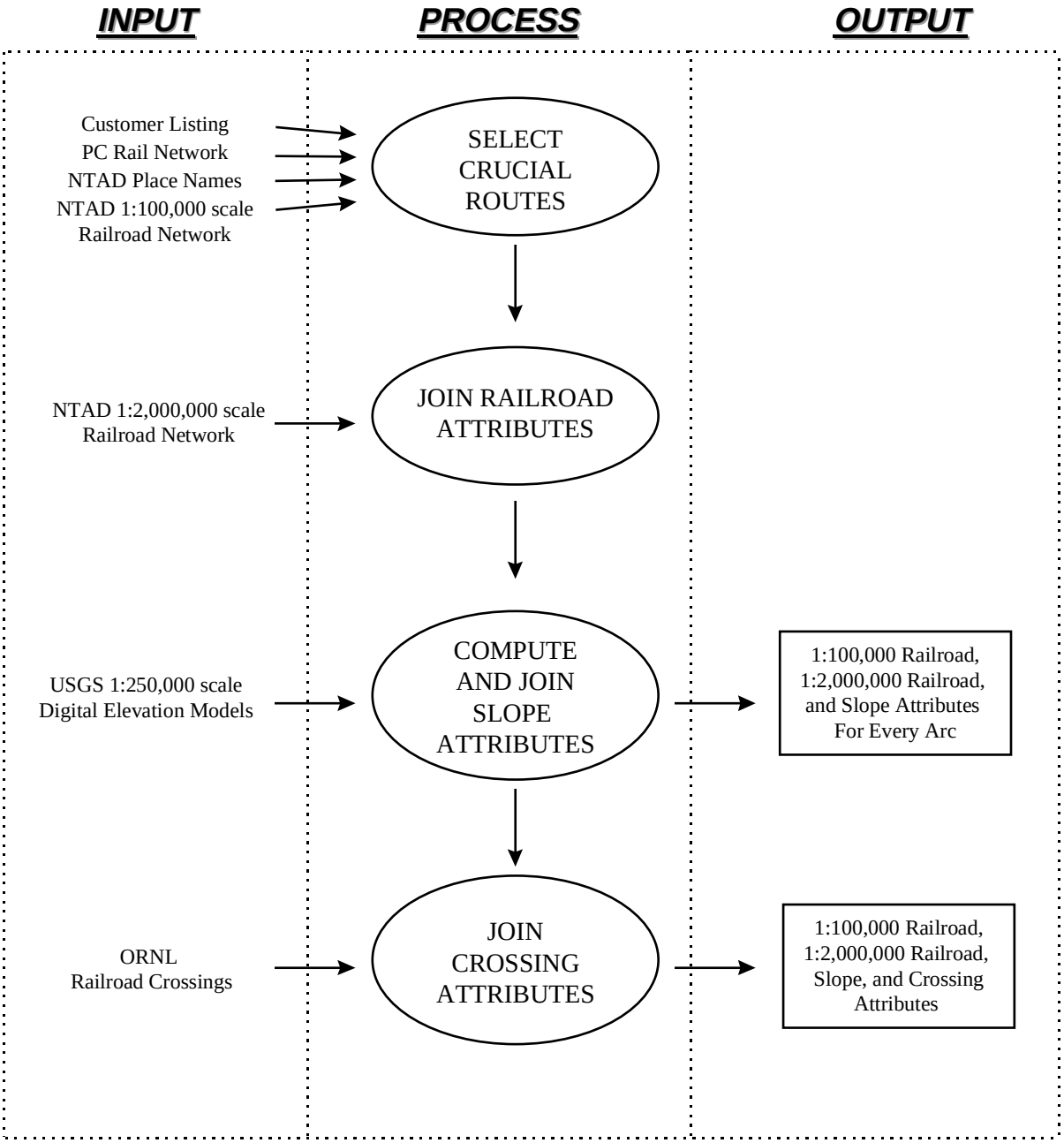

Figure 3. GIS Process Overview

Joining Railroad Network Attributes

After receiving the crucial route network, the Norris GIS Group joined the 1:2,000,000 scale NTAD railroad network attributes to it through a two step procedure. First, the following Arc/Info® commands were used to automate matching the attributes:

- ARCLABEL - to create a coverage containing the midpoint of each arc in the crucial route network.
- BUILD - to build the point topology for the coverage.
- NEAR - to place a pointer in the midpoint coverage to the nearest 1:2,000,000 scale arc (within a specified tolerance).
- JOINITEM - to join the 1:2,000,000 attributes to the midpoint coverage.
- JOINITEM - to join the midpoint coverage attributes (now containing the 1:2,000,000 attributes) back to the 1:100,000 scale crucial route network.

The primary challenge encountered in the first step was to determine the tolerance level setting so that as many attributes as possible from the 1:2,000,000 scale NTAD network could be joined without creating incorrect matches at intersections or near parallel lines. The poor topology (lack of connectivity and duplicate arcs) of the original NTAD 1:100,000 scale network was also a factor. The Arc/Info® CLEAN command was used in an attempt to lessen the problem.

After finishing the automated procedure, the second step was to make a visual pass of the network and manually correct any problems, i.e. verify that the correct 1:2,000,000 scale attributes had been joined. The crucial route network was divided into two separate coverages so that two GIS technicians could correct it simultaneously. AML macros and menus were written to aid the technicians in transferring attributes. Attributes for arcs in which a match could not be determined were set to zero. Problems encountered were mainly due to the differing topology and scale between the 1:100,000 scale crucial route network and the 1:2,000,000 scale NTAD network. The crucial route network was re-appended upon completion of the manual corrections.

Computing and Joining Slope Attributes

The next phase of the project was to compute the slope for each arc in the crucial route network and join the slope attributes to the network. As mentioned before, AML macros were used to copy each DEM from CD to a disk drive, uncompress them, and convert them to an Arc/Info® LATTICE. The slope (in percent) was then computed for each LATTICE using the Arc/Info® GRID function SLOPE. These slope LATTICEs were written to a set of 8 recordable compact disks.

ArcView® was used to review each file on the CDs for anomalies. Many of the files had 'streaks' which originated from the USGS data collection procedures, but they were not corrected (filtered) as part of the pilot project because of time constraints. There were also two anomalous rectangular areas originating from the downloaded DEMs. One was near Texas in DEM files: Brownfield-E, Clovis-E, Lubbock-W, and Plainview-W. The other was in the Norfolk-W file. Therefore, slope was not computed for network data overlaying these areas.

Arc/Info® was used to extract slope data from multiple points along the crucial route network. The following Arc/Info® commands were used:

- PROJECT - to place the network in the same coordinate space as the slope LATTICE files. (Also, the USGS quad map boundaries and names were projected so they could be used as background data).
- DENSIFYARC - to place a vertex at least every 90 meters along the crucial route network (since the slope data was based on 90 meter DEM data).
- ARCPOINT - to create a point coverage from all of the nodes and vertices contained in the crucial route network.
- BUILD - to build point topology for the new point coverage.
- SELECT & PUT - to manually divided the point coverage into smaller coverages to correspond with each DEM slope LATTICE. (Because of the large amount of data, it was necessary to process the slope data one file at a time.)
- LATTICESPOT - to extract slope values for each point along the crucial route network, therefore providing a slope value at least every 90 meters. This command was used in a series of AMLs which cycled through each point coverage alphabetically and extracted the slope data values from the set of 8 CDs.

The Tables module of Arc/Info® was used to reselect all data that did not have undefined slope values and unload them into ASCII text format files. UNIX commands were used to concatenate all of these files into one large file. The file was imported into ArcView® and the Summary Table Definition function was used to compute the minimum, maximum, variance, and average slope for each arc identification number. This tabular data was exported as an Info™ file and the Arc/Info® JOINITEM command was used to permanently join the slope information to the crucial route network. ArcView® was used to sort the network by arc ID number, add a flag for determining railroad crossing availability, and export all the arc information in ASCII comma-delimited and also dBASE format.

During this phase of the project a few files had to be reprocessed (mostly because of incorrect file names), but the main challenge was managing disk space. The GIS Group used one 4 gigabyte hard drive and four 2 gigabyte hard drives, as well as a CD writer, two CD readers, and an 8 mm tape drive.

Joining Railroad Crossing Attributes

Many of the railroad crossing data points received from ORNL did not have latitude and longitude information and, consequently, were deleted. The crucial route network attributes were then joined to the existing railroad crossing data points using the following Arc/Info® commands:

- NEAR - to place a pointer in the railroad crossing coverage to the nearest crucial route network arc (within a very small tolerance).
- JOINITEM - to join the crucial route network attributes to the railroad crossing coverage.

ArcView® was used to sort the railroad crossings by their associated arc ID number and export all the point information in ASCII comma-delimited and also dBASE format.

OUTPUT DATA

The following data were produced from the pilot project:

- 2 CDs containing USGS DEMs in GNU Zip compression format
- 2 CDs with pilot project DEMs in GNU Zip compression format
- 8 CDs with slope data for the project in Arc/Info® LATTICE format
- 9 sets of 8mm archival tapes containing pilot project data
- 2 final output files:

  1). A file in dBASE format containing attribute information from all the possible arcs considered important for calculating the line haul capacity of selected railways. See Appendix A for attribute descriptions.

  2). A file in dBASE format containing attribute information from all the railroad grade crossing points located near crucial route arcs and the attribute information from those arcs. See Appendix B for attribute descriptions.

The customer imported the two final output files into SAS, deleted any unnecessary fields, and merged the data together with other FRA data to perform the final analyses. The customer was made aware that the final output contained 78 arcs without slope data attributes. Slope attributes had not been computed for these arcs because they overlayed the anomalous DEM areas mentioned earlier. (These arcs comprised seven partial routes and one whole route.) There were also 687 duplicate arc ID numbers. Unfortunately, these had been created from the Arc/Info® CLEAN command which was used to clean up the poor topology from the base network. This problem, however, was not a serious detriment to the customer's needs since his main analysis was route-based, not arc-based.

FINAL REMARKS

There were three major difficulties in accomplishing this pilot project:

1) the lack of a topologically correct railroad network which included secondary routes,
2) the challenge of utilizing given GIS tools to accomplish an unconventional task, and
3) the lack of contiguous disk space.

As technology improves, the integrity of input data, the capability of software packages, and the speed and capacity of computer hardware will increase, thus, making a project such as this a much simpler task. Even so, we will continue to push our resources to their fullest capacity to try to solve more complicated problems.

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for the
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LIST OF ABBREVIATIONS

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FTP - File Transfer Protocol

GIS - Geographic Information System

NTAD - National Transportation Atlas Databases

ORNL - Oak Ridge National Laboratory

USGS - United States Geological Survey

INTRODUCTION

Members of the TVA Norris GIS Group accepted a project from the TVA Navigation Team in February 1997 to assist them in determining the line haul capacity of selected railroad lines in the United States. The objective of the GIS phase of the project was to merge *attribute* information from multiple transportation and topographic data sources. This was a pilot project to be accomplished in the least amount of time and finances possible — not to provide a topologically correct routing network.

The primary attributes requested by the customer were:

- specialized route identification numbers
- railroad ownership names / abbreviations
- USGS Digital Line Graph major and minor attribute codes
- density categories
- signaling system types
- slope information
- railroad grade crossing identification numbers and street names

A specialized route identification number was manually added by an undergraduate student interning with the TVA Navigation Team. The railroad ownership names and major and minor attribute codes were taken from a 1:100,000 scale railroad network provided by the Bureau of Transportation Statistics. The density and signaling information was taken from a 1:2,000,000 scale railroad network also provided by BTS. Slope information was calculated from USGS Digital Elevation Model data. Railroad grade crossing data were acquired from the Oak Ridge National Laboratory.

Because of the lack of common attribute information (no key fields), it was necessary to use a Geographic Information System to *spatially* join each database together. For instance, the 1:2,000,000 scale network arc attributes were joined to the 1:100,000 scale network arc attributes based on their proximity. Figure 1 and Tables 1, 2, and 3 illustrate the process of joining an arc from the 1:2,000,000 scale network to an arc from the 1:100,000 scale network. An example arc (Arc #1) from the 1:100,000 scale network is shown in Figure 1 and its attributes in Table 1. An example arc (Arc #99) from the 1:2,000,000 scale network is also shown in Figure 1 and its attributes are depicted in Table 2. In this example, Arc #99 is the arc nearest to Arc #1, therefore its attributes are appended to the Arc #1 attributes. The resulting attribute table is shown in Table 3.

Members of the GIS Group used this type of process to merge all of the initial databases together to produce the final output for the project (Figure 2). The GIS Group used Arc / Info® 7.0.4 and ArcView® 2.1 running on a network of Sun Ultra Workstations. The final digital data files were transferred to the customer on a network Pentium PC.

Unlike most GIS tasks, the final products of this pilot project were listings of attribute information only. In most GIS transportation applications, the primary objective is to produce a topologically correct network at a maintained scale. In this case, the emphasis was not on the connectivity of the geographic data, but on the amount of time taken to merge the attribute

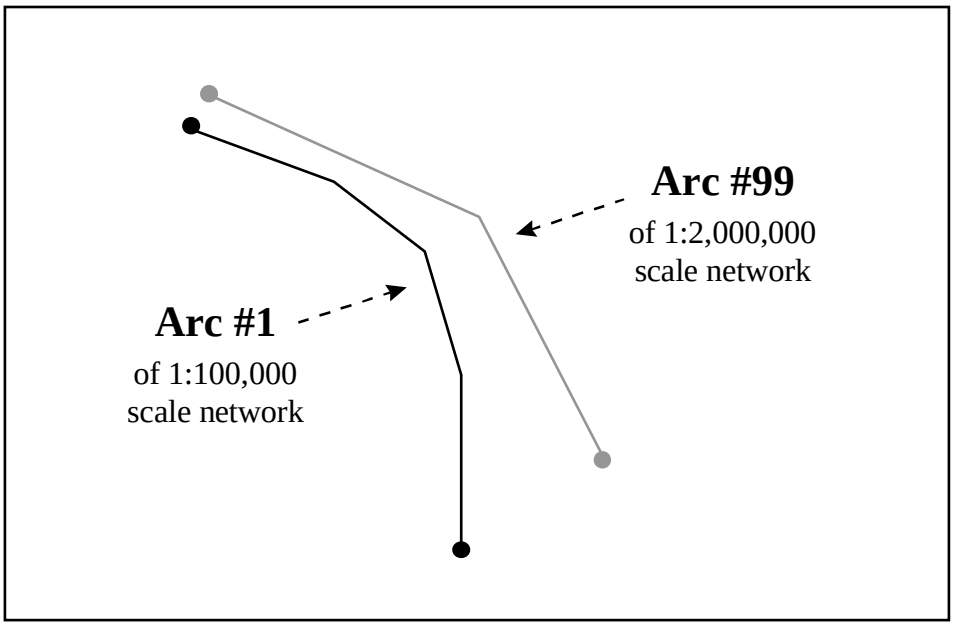

Figure 1. Spatail Join Example

Arc100k #	Route #	Owner	Major Code	Minor Code
1	2462	WC	180	208

Table 1. Example 1:100,000 Scale Railroad Network Attributes

Arc2m #	Density	Signaling
99	1.0	Manual

Table 2. Example 1:2,000,000 Scale Railroad Network Attributes

Arc100k #	Route #	Owner	Major Code	Minor Code	Arc2m #	Density	Signaling
1	2462	WC	180	208	99	1.0	Manual

Table 3. Resulting Railroad Join Attributes

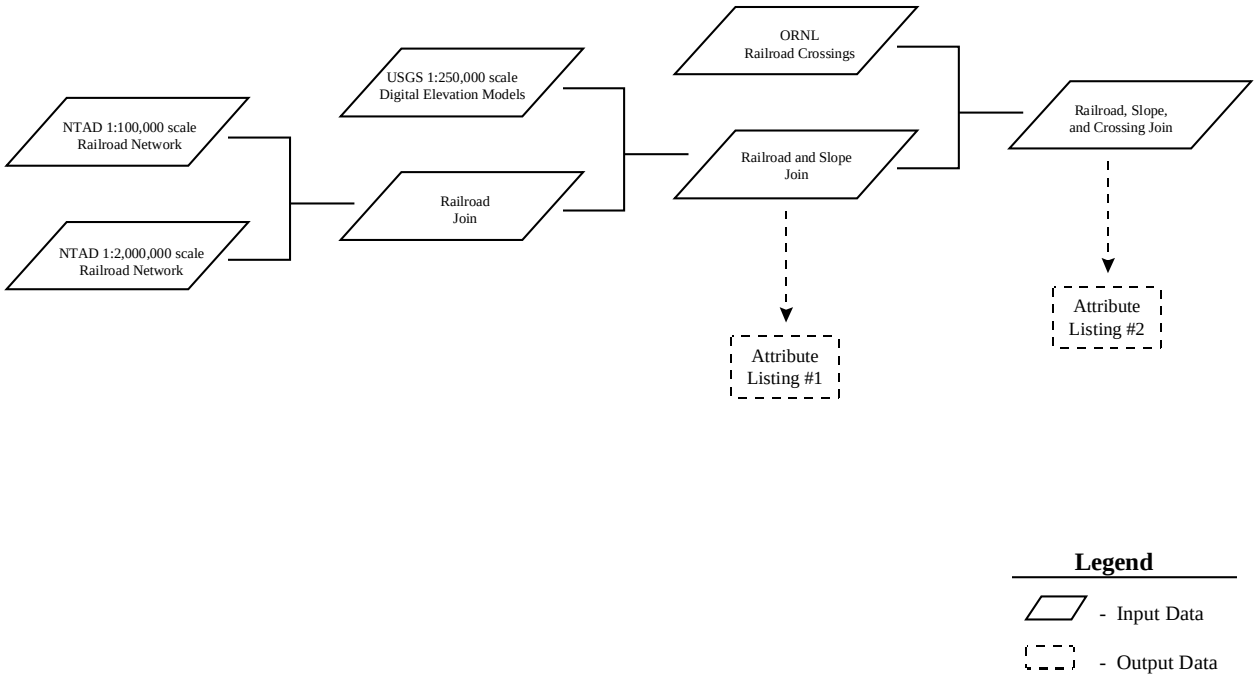

Figure 2. Multiple Joining of Input Data to Produce the Final Output Data

information together. Therefore, although the 1:100,000 scale railroad network did not maintain connectivity, it was chosen as the base network for the project since the 1:2,000,000 scale network did not contain secondary routes. For the next phase of the project, however, a topologically correct 1:100,000 scale railroad network should be available.

INPUT DATA

There were four main input data sets used for the project:

1). 1:100,000 scale railroad network taken from the 1995 National Transportation Atlas Databases (NTAD) compact disc. The CD was ordered via the Department of Transportation's Bureau of Transportation Statistics website: **http://www.bts.gov**
C code and ARC Macro Language (AML) routines were written to import the data into Arc/Info®.

2). 1:2,000,000 scale railroad network taken from the 1996 National Transportation Atlas Databases (NTAD) compact disc. The CD was ordered via the Department of Transportation's Bureau of Transportation Statistics website: **http://www.bts.gov**
The data was imported into Arc/Info® using an AML macro downloaded from the internet (btsarc.aml) and a user written AML macro routine.

3). 1:250,000 Digital Elevation Models downloaded from the United States Geological Survey website: **http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/index1m.html**
The DEMs were downloaded from the internet and copied to recordable compact disks. Another set of CDs was also made which contained only those DEMs thought to be necessary for the project. AML macros were written to copy each of these DEMs from CD to a disk drive, uncompress them, and use the Arc/Info® DEMLATTICE command to convert them to an Arc/Info® LATTICE.

4). Railroad grade crossing data received from Bruce Peterson of the Oak Ridge National Laboratory via FTP. The railroad crossing data were imported into Arc/Info® manually using Info™ commands.

In addition, the Navigation Team student used an Arc/Info® coverage of the 1995 NTAD Place Names provided by the Norris GIS Group, and a list of railroad routes along with a PC Rail© network provided by the customer.

PROCESS OVERVIEW

A simplified graphical description of the GIS process is shown in Figure 3. Crucial network routes were first extracted from the NTAD 1:100,000 scale network to create a new, reduced network. Attributes from the NTAD 1:2,000,000 scale network were then joined to the new 'crucial route network'. Slope attributes were calculated for each arc in the new network and an output listing was created which contained all attribute information for every arc. Afterwards, the network arc attributes were joined to the railroad crossing point attributes and another output listing was created. Both output listings were then delivered to the customer.

Selecting Crucial Routes

A list of crucial railroad routes was defined and provided by the customer along with a PC Rail© railroad network to the Navigation Team undergraduate intern. For each route on the list provided, the intern used the origin, destination, and ownership names to visually locate the route on the PC Rail© network on a desktop PC. A Sun workstation running Arc/Info® was used to visually locate the identical route on the 1:100,000 scale network. The arcs for the route were <u>select</u>ed[1] in ArcEdit and <u>put</u> into (appended to) a new data layer. A unique identification number was manually assigned to each route via the listing received from the customer. The final Arc/Info® output coverage containing the crucial routes was then given to the Norris GIS Group. Because of some of the following problems, not all routes were matched.

1. The two networks were not displayed in the same projection. The 1:100,000 scale network was in a Geographic coordinate system (latitude and longitude in decimal degrees) and the PC Rail© network projection was unknown.
2. There were discrepancies amongst railroad ownership names.
3. The topology differed between the two networks.

[1] Arc/Info® commands are underlined

GIS PROCESS OVERVIEW

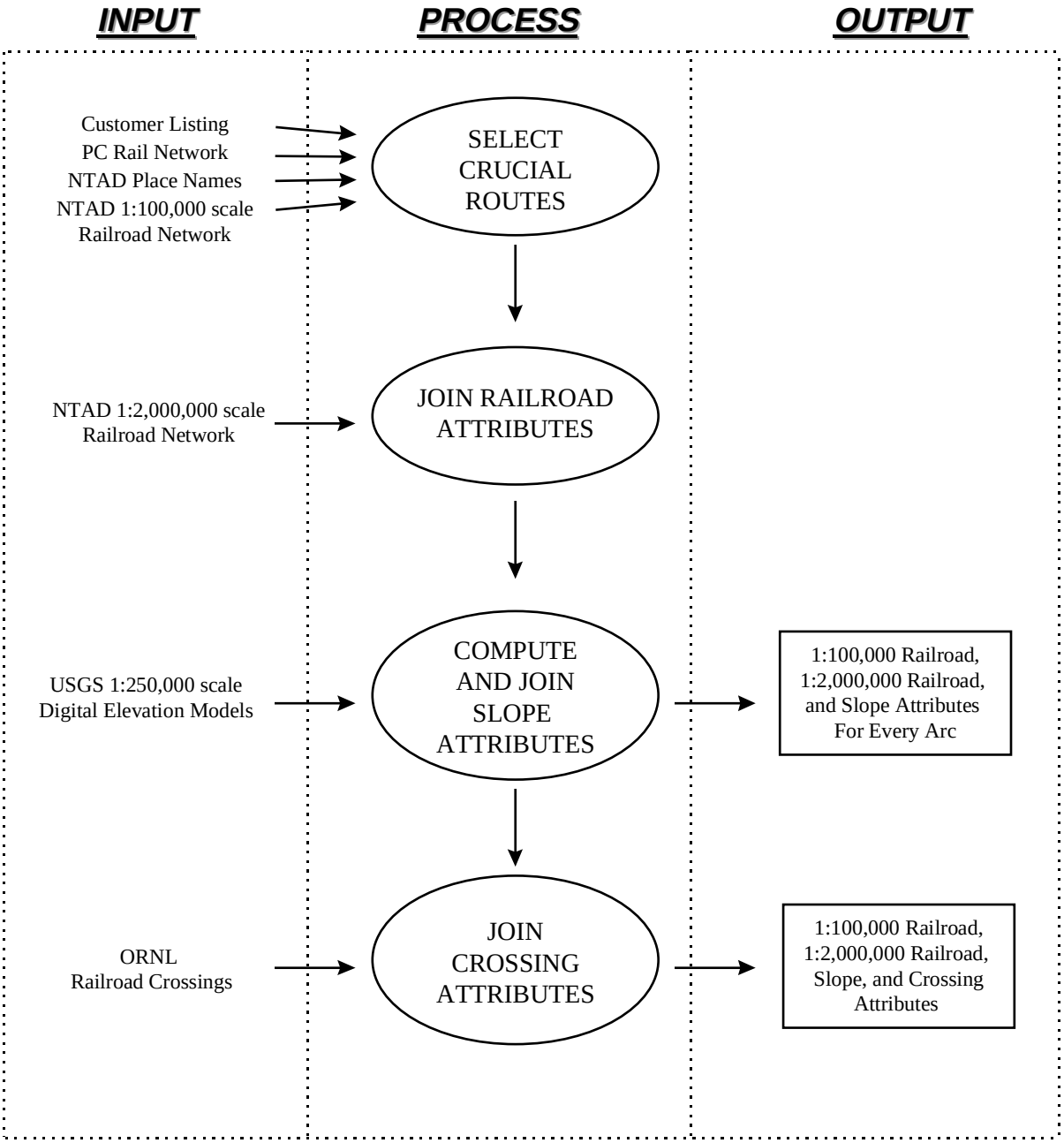

Figure 3. GIS Process Overview

Joining Railroad Network Attributes

After receiving the crucial route network, the Norris GIS Group joined the 1:2,000,000 scale NTAD railroad network attributes to it through a two step procedure. First, the following Arc/Info® commands were used to automate matching the attributes:

- ARCLABEL - to create a coverage containing the midpoint of each arc in the crucial route network.
- BUILD - to build the point topology for the coverage.
- NEAR - to place a pointer in the midpoint coverage to the nearest 1:2,000,000 scale arc (within a specified tolerance).
- JOINITEM - to join the 1:2,000,000 attributes to the midpoint coverage.
- JOINITEM - to join the midpoint coverage attributes (now containing the 1:2,000,000 attributes) back to the 1:100,000 scale crucial route network.

The primary challenge encountered in the first step was to determine the tolerance level setting so that as many attributes as possible from the 1:2,000,000 scale NTAD network could be joined without creating incorrect matches at intersections or near parallel lines. The poor topology (lack of connectivity and duplicate arcs) of the original NTAD 1:100,000 scale network was also a factor. The Arc/Info® CLEAN command was used in an attempt to lessen the problem.

After finishing the automated procedure, the second step was to make a visual pass of the network and manually correct any problems, i.e. verify that the correct 1:2,000,000 scale attributes had been joined. The crucial route network was divided into two separate coverages so that two GIS technicians could correct it simultaneously. AML macros and menus were written to aid the technicians in transferring attributes. Attributes for arcs in which a match could not be determined were set to zero. Problems encountered were mainly due to the differing topology and scale between the 1:100,000 scale crucial route network and the 1:2,000,000 scale NTAD network. The crucial route network was re-appended upon completion of the manual corrections.

Computing and Joining Slope Attributes

The next phase of the project was to compute the slope for each arc in the crucial route network and join the slope attributes to the network. As mentioned before, AML macros were used to copy each DEM from CD to a disk drive, uncompress them, and convert them to an Arc/Info® LATTICE. The slope (in percent) was then computed for each LATTICE using the Arc/Info® GRID function SLOPE. These slope LATTICEs were written to a set of 8 recordable compact disks.

ArcView® was used to review each file on the CDs for anomalies. Many of the files had 'streaks' which originated from the USGS data collection procedures, but they were not corrected (filtered) as part of the pilot project because of time constraints. There were also two anomalous rectangular areas originating from the downloaded DEMs. One was near Texas in DEM files: Brownfield-E, Clovis-E, Lubbock-W, and Plainview-W. The other was in the Norfolk-W file. Therefore, slope was not computed for network data overlaying these areas.

Arc/Info® was used to extract slope data from multiple points along the crucial route network. The following Arc/Info® commands were used:

- PROJECT - to place the network in the same coordinate space as the slope LATTICE files. (Also, the USGS quad map boundaries and names were projected so they could be used as background data).
- DENSIFYARC - to place a vertex at least every 90 meters along the crucial route network (since the slope data was based on 90 meter DEM data).
- ARCPOINT - to create a point coverage from all of the nodes and vertices contained in the crucial route network.
- BUILD - to build point topology for the new point coverage.
- SELECT & PUT - to manually divided the point coverage into smaller coverages to correspond with each DEM slope LATTICE. (Because of the large amount of data, it was necessary to process the slope data one file at a time.)
- LATTICESPOT - to extract slope values for each point along the crucial route network, therefore providing a slope value at least every 90 meters. This command was used in a series of AMLs which cycled through each point coverage alphabetically and extracted the slope data values from the set of 8 CDs.

The Tables module of Arc/Info® was used to reselect all data that did not have undefined slope values and unload them into ASCII text format files. UNIX commands were used to concatenate all of these files into one large file. The file was imported into ArcView® and the Summary Table Definition function was used to compute the minimum, maximum, variance, and average slope for each arc identification number. This tabular data was exported as an Info™ file and the Arc/Info® JOINITEM command was used to permanently join the slope information to the crucial route network. ArcView® was used to sort the network by arc ID number, add a flag for determining railroad crossing availability, and export all the arc information in ASCII comma-delimited and also dBASE format.

During this phase of the project a few files had to be reprocessed (mostly because of incorrect file names), but the main challenge was managing disk space. The GIS Group used one 4 gigabyte hard drive and four 2 gigabyte hard drives, as well as a CD writer, two CD readers, and an 8 mm tape drive.

Joining Railroad Crossing Attributes

Many of the railroad crossing data points received from ORNL did not have latitude and longitude information and, consequently, were deleted. The crucial route network attributes were then joined to the existing railroad crossing data points using the following Arc/Info® commands:

- NEAR - to place a pointer in the railroad crossing coverage to the nearest crucial route network arc (within a very small tolerance).
- JOINITEM - to join the crucial route network attributes to the railroad crossing coverage.

ArcView® was used to sort the railroad crossings by their associated arc ID number and export all the point information in ASCII comma-delimited and also dBASE format.

OUTPUT DATA

The following data were produced from the pilot project:

- 2 CDs containing USGS DEMs in GNU Zip compression format
- 2 CDs with pilot project DEMs in GNU Zip compression format
- 8 CDs with slope data for the project in Arc/Info® LATTICE format
- 9 sets of 8mm archival tapes containing pilot project data
- 2 final output files:

  1). A file in dBASE format containing attribute information from all the possible arcs considered important for calculating the line haul capacity of selected railways. See Appendix A for attribute descriptions.

  2). A file in dBASE format containing attribute information from all the railroad grade crossing points located near crucial route arcs and the attribute information from those arcs. See Appendix B for attribute descriptions.

The customer imported the two final output files into SAS, deleted any unnecessary fields, and merged the data together with other FRA data to perform the final analyses. The customer was made aware that the final output contained 78 arcs without slope data attributes. Slope attributes had not been computed for these arcs because they overlayed the anomalous DEM areas mentioned earlier. (These arcs comprised seven partial routes and one whole route.) There were also 687 duplicate arc ID numbers. Unfortunately, these had been created from the Arc/Info® CLEAN command which was used to clean up the poor topology from the base network. This problem, however, was not a serious detriment to the customer's needs since his main analysis was route-based, not arc-based.

FINAL REMARKS

There were three major difficulties in accomplishing this pilot project:

1) the lack of a topologically correct railroad network which included secondary routes,
2) the challenge of utilizing given GIS tools to accomplish an unconventional task, and
3) the lack of contiguous disk space.

As technology improves, the integrity of input data, the capability of software packages, and the speed and capacity of computer hardware will increase, thus, making a project such as this a much simpler task. Even so, we will continue to push our resources to their fullest capacity to try to solve more complicated problems.

APPENDIX
A

Output File #1 Attribute Descriptions

OUTPUT FILE #1 ATTRIBUTE DESCRIPTIONS

1: 100,000 Railroad Network Attributes

MARKFINAL#: Record number generated by Arc/Info®

MARKFINAL-ID: Arc ID number taken from the original 1995 NTAD 1:100,000 scale railroad network

[2]FROMNODE: Node ID in rail_100.pnt

[2]TONODE: Node ID in rail_100.pnt

[2]LINKID: Unique identification number

[2]LINKLEN: Link length

[2]DIRECTION: Always 0

[2]MAJORATT: Major attribute code from USGS digital line graphs

- 180 Transportation systems - railroads
- 181 Railroads: minor attribute indicates number of tracks
- 188 Best estimate of position or classification
- 189 Coincident feature

[2]MINORATT: Minor attribute code from USGS digital line graphs

- 0001 Bridge abutment
- 0002 Tunnel portal
- 0007 Drawbridge
- 0100 Void area
- 0201 Railroad
- 0202 Railroad in street or road
- 0204 Carline
- 0205 Cog railroad, incline railway, logging tram
- 0207 Ferry crossing
- 0208 Railroad siding
- 0209 Perimeter or limit of yard
- 0210 Arbitrary line extension
- 0211 Closure line
- 0400 Railroad station, perimeter of station
- 0401 Turntable
- 0402 Roundhouse
- 0600 Historical
- 0601 In tunnel
- 0602 Overpassing, on bridge
- 0603 Abandoned
- 0604 Dismantled
- 0605 Underpassing
- 0606 Narrow gauge
- 0607 In snowshed or under structure
- 0608 Under construction
- 0609 Elevated
- 0610 Rapid transit
- 0611 On drawbridge

[2] Taken from the 1995 NTAD rail_100.lin file. Refer to the CDs rail_100.txt file for further description.

	0612 Private
	0613 U.S. Government
	0614 Juxtaposition
	0000 Photorevised feature
	Note: If major attribute is 181 then minor attribute is number of tracks.
[2]OWNER:	Alphanumeric identifier of the owning railroad
ROUTEID:	Mark Burton's route ID number added by Cathy Adams

1: 2 million Railroad Network Attributes

NRAIL2M#:	Record number generated by Arc/Info®
NRAIL2M-ID:	Arc ID number taken from the original 1996 NTAD 1:2,000,000 scale railroad network
[3]LRECTYPE:	Link record type: always 'L'
[3]LVERSION:	Link file version number
[3]LREVISION:	Link record revision number
[3]LMODDATE:	Link record modification date
[3]LINKID2M:	Unique sequential line identification
[3]FEATUREID:	Unique line identification
[3]ANODE:	Node identification for the beginning node of the line
[3]BNODE:	Node identification for the ending node of the line
[3]DESCRIPT:	Name or identification for the line feature
[3]STFIPS1:	Primary State FIPS Code
[3]STFIPS2:	Secondary State FIPS Code
[4]RECTYPE:	Text record type: Always 'T'
[4]VERSION:	Text file version number
[4]REVISION:	Text record revision number
[4]MODDATE:	Text record modification date
[4]OVERLAY:	Country marker
[4]RROWN1:	First railroad owner name
[4]RROWN2:	Second railroad owner name
[4]RROWN3:	Third railroad owner name
[4]TR1:	First railroad having trackage rights
[4]TR2:	Second railroad having trackage rights
[4]TR3:	Third railroad having trackage rights
[4]TR4:	Fourth railroad having trackage rights
[4]TR5:	Fifth railroad having trackage rights
[4]TR6:	Sixth railroad having trackage rights
[4]TR7:	Seventh railroad having trackage rights
[4]TR8:	Eighth railroad having trackage rights
[4]TR9:	Ninth railroad having trackage rights
[4]SSRR:	Subsidiary railroad

[3] Taken from the 1996 NTAD rail2m.lnk file. Refer to the CDs rail_2m.met file for further description.

[4] Taken from the 1996 NTAD rail2m.tl1 file. Refer to the CDs rail_2m.met file for further description.

[4]PRR1:	First previous Railroad owner
[4]PRR2:	Second previous railroad owner
[4]ABDN:	Abandoned flag
[4]PASS:	Type of passenger rail flag
[4]MIL:	Military importance flag
[4]STATE:	Postal Code
[4]USGS_REG:	USGS Region Code
[4]FRA_REG:	FRA Region Code
[4]DENSITY:	Density Category
[4]RR_CLS:	Railroad classification
[4]SIGNALS:	Type of signaling system
[4]ABDYR:	Abandonment Year
[4]STFIPS:	State FIPS Code

Slope Attributes Generated from USGS DEM Data

COUNT:	Number of slope sample points for this arc
MIN_SLOPE:	Slope minimum for this arc (percent rise)
MAX_SLOPE:	Slope maximum for this arc (percent rise)
VAR_SLOPE:	Slope variance for this arc
AVE_SLOPE:	Slope average for this arc

Railroad Crossing Attributes

XING: Flag for determining if this arc has associated railroad crossing data:
"1" - means associated railroad crossing data exists,
otherwise the field is blank.

APPENDIX
B

Output File #2 Attribute Descriptions

OUTPUT FILE #2 ATTRIBUTE DESCRIPTIONS

Railroad Crossing Attributes

MARKXINGS#: Record number generated by Arc/Info®
MARKXINGS-ID: Arc/Info® Point ID number
[5]GCIS_ID: Railroad Crossing ID number (same as FRA ID)
[5]X_DD: Longitude of the railroad crossing
[5]Y_DD: Latitude of the railroad crossing
[5]SOURCE: "V" - means located by Paul Cheng in TIGER with a street name or railroad match
"M" (by milepoint) - interpolated between V's
[5]RR: Ownership name abbreviation for the railroad crossing
[5]DIVISION: Division
[5]SUB_BRANCH: Sub/branch
[5]MP: Milepoint
[5]STREET: Street name of the railroad grade crossing

1: 100,000 Railroad Network Attributes

MARKFINAL#: Record number generated by Arc/Info®
MARKFINAL-ID: Arc ID number taken from the original 1995 NTAD 1:100,000 scale rail network
[6]FROMNODE: Node ID in rail_100.pnt
[6]TONODE: Node ID in rail_100.pnt
[6]LINKID: Unique identification number
[6]LINKLEN: Link ID number
[6]DIRECTION: Always 0
[6]MAJORATT: Major attribute code from USGS digital line graphs

180	Transportation systems - railroads
181	Railroads: minor attribute indicates number of tracks
188	Best estimate of position or classification
189	Coincident feature

[6]MINORATT: Minor attribute code from USGS digital line graphs

0001	Bridge abutment
0002	Tunnel portal
0007	Drawbridge
0100	Void area
0201	Railroad
0202	Railroad in street or road
0204	Carline
0205	Cog railroad, incline railway, logging tram
0207	Ferry crossing

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[5] Taken from data provided by Bruce Peterson of the Oak Ridge National Laboratory.

[6] Taken from the 1995 NTAD rail_100.lin file. Refer to the CDs rail_100.txt file for further description.

0208	Railroad siding
0209	Perimeter or limit of yard
0210	Arbitrary line extension
0211	Closure line
0400	Railroad station, perimeter of station
0401	Turntable
0402	Roundhouse
0600	Historical
0601	In tunnel
0602	Overpassing, on bridge
0603	Abandoned
0604	Dismantled
0605	Underpassing
0606	Narrow gauge
0607	In snowshed or under structure
0608	Under construction
0609	Elevated
0610	Rapid transit
0611	On drawbridge
0612	Private
0613	U.S. Government
0614	Juxtaposition
0000	Photorevised feature

Note: If major attribute is 181 then minor attribute is number of tracks.

[6]OWNER: Alphanumeric identifier of the owning railroad

ROUTEID: Mark Burton's route ID number added by Cathy Adams

1: 2 million Railroad Network Attributes

NRAIL2M#: Record number generated by Arc/Info®

NRAIL2M-ID: Arc ID number taken from the original 1996 NTAD 1:2,000,000 scale railroad network

[7]LRECTYPE: Link record type: always 'L'

[7]LVERSION: Link file version number

[7]LREVISION: Link record revision number

[7]LMODDATE: Link record modification date

[7]LINKID2M: Unique sequential line identification

[7]FEATUREID: Unique line identification

[7]ANODE: Node identification for the beginning node of the line

[7]BNODE: Node identification for the ending node of the line

[7]DESCRIPT: Name or identification for the line feature

[7]STFIPS1: Primary State FIPS Code

[7]STFIPS2: Secondary State FIPS Code

[7] Taken from the 1996 NTAD rail2m.lnk file. Refer to the CDs rail_2m.met file for further description.

[8]RECTYPE:	Text record type: Always 'T'
[8]VERSION:	Text file version number
[8]REVISION:	Text record revision number
[8]MODDATE:	Text record modification date
[8]OVERLAY:	Country marker
[8]RROWN1:	First railroad owner name
[8]RROWN2:	Second railroad owner name
[8]RROWN3:	Third railroad owner name
[8]TR1:	First railroad having trackage rights
[8]TR2:	Second railroad having trackage rights
[8]TR3:	Third railroad having trackage rights
[8]TR4:	Fourth railroad having trackage rights
[8]TR5:	Fifth railroad having trackage rights
[8]TR6:	Sixth railroad having trackage rights
[8]TR7:	Seventh railroad having trackage rights
[8]TR8:	Eighth railroad having trackage rights
[8]TR9:	Ninth railroad having trackage rights
[8]SSRR:	Subsidiary railroad
[8]PRR1:	First previous Railroad owner
[8]PRR2:	Second previous railroad owner
[8]ABDN:	Abandoned flag
[8]PASS:	Type of passenger rail flag
[8]MIL:	Military importance flag
[8]STATE:	Postal Code
[8]USGS_REG:	USGS Region Code
[8]FRA_REG:	FRA Region Code
[8]DENSITY:	Density Category
[8]RR_CLS:	Railroad classification
[8]SIGNALS:	Type of signaling system
[8]ABDYR:	Abandonment Year
[8]STFIPS:	State FIPS Code

Slope Attributes Generated from USGS DEM Data

COUNT:	Number of slope sample points for this arc
MIN_SLOPE:	Slope minimum for this arc (percent rise)
MAX_SLOPE:	Slope maximum for this arc (percent rise)
VAR_SLOPE:	Slope variance for this arc
AVE_SLOPE:	Slope average for this arc

[8] Taken from the 1996 NTAD rail2m.tl1 file. Refer to the CDs rail_2m.met file for further description.

GIS PROCESS OVERVIEW
for
PHASE 2
of the
RAILROAD LINE-HAUL CAPACITY PROJECT

Geographic Information Systems Team
Tennessee Valley Authority
Norris, Tennessee

March 1998

Contributing Norris GIS Team Members:

GIS Project Leader:	Pamela J. Nabors
GIS Senior Technician:	Garry E. Chappelle
GIS Technician:	Veronica A. Long
GIS Technician:	Larry E. Shelton
GIS Technician:	Deborah K. Smith
Arc/Info Consultant:	David A. Hankins

with

Navigation Team GIS Specialist:	M. Carolyn Koroa
Navigation Team GIS Intern:	Jim W. Cunningham

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LIST OF ABBREVIATIONS

AML - Arc Macro Language

BTS - Bureau of Transportation Statistics

FTP - File Transfer Protocol

GIS - Geographic Information System

NTAD - National Transportation Atlas Databases

INTRODUCTION

In late June 1997, the TVA Navigation Team employed members of the TVA Norris GIS Team to conduct the second phase of a research and development project for determining the line-haul capacity of selected railroad lines in the United States. The objective was to use a Geographic Information System to simulate routing railroad shipments over a digital line network and produce a list of specialized route identification numbers for the customer. An overview of the process is graphically depicted in Figure 1. The input data, processes, and output data are discussed further in the following sections.

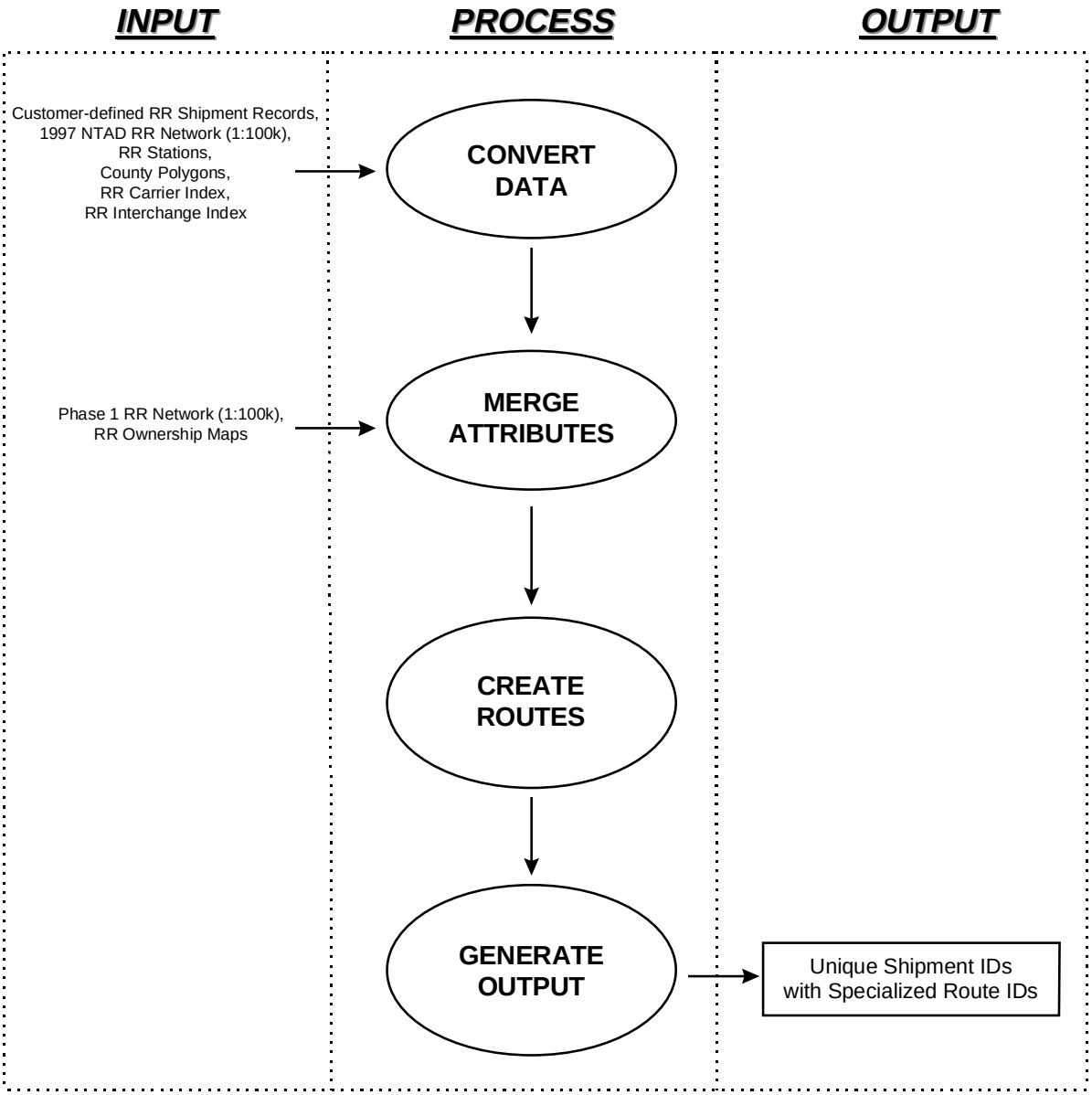


Figure 1. GIS Process Overview for Phase 2.

INPUT DATA

There were eight input data sets used for the project (as shown in Figure 1):

1). Customer-defined railroad shipment records. The customer originally sent about 500,000 shipment records to be routed. These records were generated from the 1995 Carload Waybill Sample and represented 2-3% of all railroad movements for that year. Since a separate record existed for each *type* of shipment (coal, corn, etc.), many of these shipment records had the same route (i.e., same origin, destination, and railroad owner). Therefore, after we discovered the large amount of time required to route so many shipments using Arc/Info, Dr. Burton combined duplicate shipment routes and generated a unique identifier for each group. The new, pared shipment data set contained about 75,000 records with the following attributes:

FIELD NAME	*DESCRIPTION*
UNIQUE	Unique Shipment Identifier Assigned by Dr. Mark Burton
OFSAC	Originating Station FSAC Code
ORR	Originating Railroad American Association of Railroads Number (AARNO)
INT1	First Interchange Location Alpha Code
RR2	Second Railroad American Association of Railroads Number
INT2	Second Interchange Location Alpha Code
RR3	Third Railroad American Association of Railroads Number
INT3	Third Interchange Location Alpha Code
RR4	Fourth Railroad American Association of Railroads Number
INT4	Fourth Interchange Location Alpha Code
TRR	Terminating Railroad American Association of Railroads Number
TFSAC	Terminating Station FSAC Code
NUMRR	Number of Shipment Segments
OFIP	Originating County FIPS Code
TFIP	Terminating County FIPS Code

2). 1997 NTAD 1:100,000 scale U. S. railroad network (see website http://www.bts.gov). A pre-release version was acquired through the Department of Transportation's Bureau of Transportation Statistics and used as the underlying topology for the project. Refer to the rail100k.met metadata file on the 1997 NTAD compact disc for more details.

3). Railroad station data purchased from Alber Leland, Inc. A completed data set was not available at the beginning of the project, so a preliminary copy of the data was delivered in August 1997. An updated preliminary version was delivered again in October and used as the final data set. Station data contained the following coordinate information (from the RCOORUS file):

FIELD NAME	*DESCRIPTION*
STATION_ID	Unique Station Identifier
LATITUDE	Latitude of Railroad Station in Decimal Degrees
LONGITUDE	Longitude of Railroad Station in Decimal Degrees

and attribute information (from the RAILUS file):

FIELD NAME	*DESCRIPTION*
STATION_ID	Unique Station Identifier
STAT_NAME	Name of Railroad Station
STAT_STATE	State Name of Railroad Station
STAT_COUNT	County Name of Railroad Station
FSAC	Freight Station Accounting Code, *Corresponds with Shipment Record's* OFSAC, TFSAC *Attributes*
OPSL	Open and Prepaid Station List Number
SPLC	Standard Point Location Code
ZIPCODE	Rating Zip Code
SCAC	Serving Carrier Standard Carrier Alpha Code

4). County polygons. The county shapefiles on the "ESRI Data & Maps, Volume 1" compact disc provided with ESRI's ArcView 3.0 were used to provide county polygon data with the following information:

FIELD NAME	*DESCRIPTION*
NAME	Name of County
STATE_NAME	State Name of Residing County
FIPS	Full County FIPS Code, *Corresponds with Shipment Record's* OFIP, TFIP *Attributes*

5). Railroad carrier index provided by the Navigation Team. This index was created to provide a link between the customer's shipment records and the Alber Leland station records via the given carrier information. To do this, a list was first generated of all the American Association of Railroads numbers (AARNO) occurring in the shipment records (ORR, RR2, RR3, RR4, TRR). Carrier name alpha codes (ALPHA) were then added for each AARNO using the Official Railway Guide as a reference.

FIELD NAME	*DESCRIPTION*
ALPHA	Railroad Carrier Alpha Code (carrier name abbreviation), *Corresponds with Station List's* SCAC *Attribute*
CARRIER_NAME	Full Name of Railroad Carrier
AARNO	American Association of Railroads Number, *Corresponds with Shipment Record's* ORR, RR2, RR3, RR4, TRR *Attributes*

6). Railroad interchange index provided by the Navigation Team. This index was created to provide a link between the customer's shipment records and the Alber Leland station records for interchange points. First, a list was generated of all the interchange codes (INT_CODE) occurring in the shipment records (INT1, INT2, INT3, INT4). Corresponding interchange names and state names (INTERCHANGE, INT_STATE) were then added using the Open and Prepaid Station List as a reference.

FIELD NAME	*DESCRIPTION*
INT_CODE	Interchange Alpha Code (interchange name abbreviation), *Corresponds with Shipment Record's* INT1, INT2, INT3, INT4 *Attributes*
INTERCHANGE	Interchange Full Name, *Corresponds with Station List's* STAT_NAME *Attribute*
INT_STATE	State Name of Residing Interchange, *Corresponds with Station List's* STAT_STATE *Attribute*

7). Specialized 1995 NTAD railroad network (1:100,000 scale) with Phase 1 attributes. The specialized route identification numbers (ROUTEID field) and railroad ownership attributes from the Phase 1 network were reused in Phase 2. Ownership attributes from Phase 1 included the OWNER field from the 1995 NTAD railroad network (1:100,000 scale), and the RROWN1, RROWN2, RROWN3 fields from 1996 NTAD railroad network (1:2,000,000 scale). Refer to the Phase 1 documentation (May 1997) for a more detailed description of the Phase 1 attribute data.

8). Ownership information. Various paper maps produced by individual railroad carriers were used to add ownership attributes when necessary.

PROCESS OVERVIEW

Phase 2 of the GIS railroad line-haul capacity project was conducted using Arc/Info 7.0.4 and ArcView 3.0 running on a network of Sun workstations and Pentium PCs. The following sections describe how the input data were converted, attributes were merged, routes were created, and output was generated.

CONVERT DATA

1). Railroad shipment records were converted from an ASCII columnar format to INFO database format using an AML macro. The macro used the Tables module *DEFINE*[1] command, and the Info module *SEL* command and *GET* command (with the *COPY* and *ASCII* options). The *CHANGE* command from the Tables module of Arc/Info was then used to strip trailing blanks from the interchange fields (INT1, INT2, INT3, INT4).

2). The 1997 NTAD 1:100,000 scale railroad network was converted using the BTS bts2arc.aml conversion macro (see website http://www.bts.gov/gis/ntatlas/btsarc.aml).

3). The railroad station coordinate data purchased from Alber Leland, Inc. was converted by using the Arc/Info *GENERATE* command. The **station attribute data** was received with double quotes around each item, so all data were imported into Info as character fields, then the FSAC field was converted to integer and divided by 100.

[1] Arc/Info commands are capitalized and italicized in this document.

4). **U.S. county polygon shapefiles** from the "ESRI Data & Maps, Volume 1" compact disc were copied to a UNIX hard drive and converted to an Arc/Info coverage using the following commands: *SHAPEARC*, *CLEAN*, *REGIONPOLY*.

5). **The railroad carrier index** provided by the Navigation Team was exported from MicroSoft Excel into dBASE IV format and copied to a UNIX hard drive. The data were then converted to Info format using the *DBASEINFO* command.

6). **The railroad interchange** index provided by the Navigation Team was exported from MicroSoft Excel into dBASE IV format and copied to a UNIX hard drive. The *DBASEINFO* command was used to convert the data to Info format.

7). No conversion was necessary for the **Phase 1 network**.

8). No conversion was necessary for using the paper **ownership maps**.

MERGE ATTRIBUTES

Assemble Network Attributes

Attributes from the railroad network used in Phase 1 of this project were transferred to the new Phase 2 network (1997 NTAD 1:100,000 scale) using the *NEAR* and *JOINITEM* Arc/Info commands. A visual check of the network was made along with any necessary manual corrections, especially for the Phase 1 specialized route numbers (ROUTEID field). Only the ROUTEID, ownership, and state FIPS attributes were preserved on the new network. Therefore, the new network attributes were:

FIELD NAME	*DESCRIPTION*
STFIPS	State FIPS Code
RROWNER	1997 NTAD 1:100k Railroad Owner Name Abbreviation
ROUTEID	Dr. Mark Burton's Specialized Route Identification Number
OWNER	1995 NTAD 1:100k Railroad Owner Name Abbreviation
RROWN1	1996 NTAD 1:2mill First Railroad Owner Name Abbreviation
RROWN2	1996 NTAD 1:2mill Second Railroad Owner Name Abbreviation
RROWN3	1996 NTAD 1:2mill Third Railroad Owner Name Abbreviation

The 1997 NTAD 1:100,000 scale network did not have adequate ownership information, so ownership information from the Phase 1 network was combined with it to produce a new data field: COMBO_OWN, and the other ownership fields were dropped. Ownership was assigned in the following priority to emulate actual 1995 ownership as close as possible:

1.) 1996 NTAD 1:2,000,000 scale ownership attributes (RROWN1, RROWN2, RROWN3),
2.) 1995 NTAD 1:100,000 scale ownership attributes (OWNER), then
3.) 1997 NTAD 1:100,000 scale attributes (RROWNER).

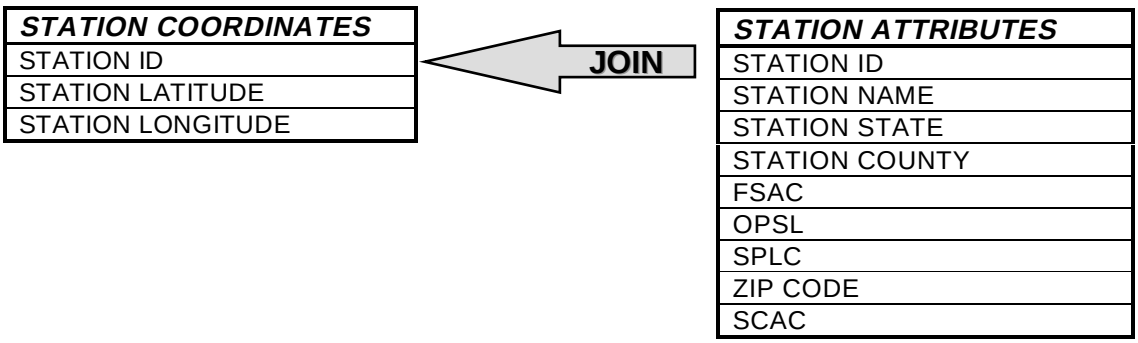
Even after combining all ownership fields, only about 60% of the arcs had ownership attributes. So, the network was transferred to the Navigation Team GIS specialist and intern who used

various paper maps produced by individual railroad carriers to manually enter additional ownership information. To save time during the editing process, the Phase 2 railroad network was divided into 2 parts (eastern and western U.S.) and worked on simultaneously. The western portion was *EXPORT*ed and FTPed to the Navigation Team UNIX workstation and edited with Arc/Info. The eastern portion was converted via *ARCSHAPE*[2] and transferred to their PC and edited with ArcView 3.0a. Upon completion of their manual edits, the network was transferred back to the Norris GIS Team. The eastern network was converted back to a UNIX coverage using *SHAPEARC*, and the western network was *IMPORT*ed. After *APPEND*ing the eastern and western portions back together, the network was spot checked for topological and attribute errors. Two more data fields were then added for calculating and displaying routes. Therefore, the final railroad network contained the following arc attributes:

FIELD NAME	*DESCRIPTION*
STFIPS	State FIPS Code
ROUTEID	Dr. Mark Burton's Route Identification Number
COMBO_OWN	Ownership Alpha Code - compiled from multiple sources
IMPEDE	Impedance value for calculating a route
IMPEDESYM	Arc/Info drawing symbol code

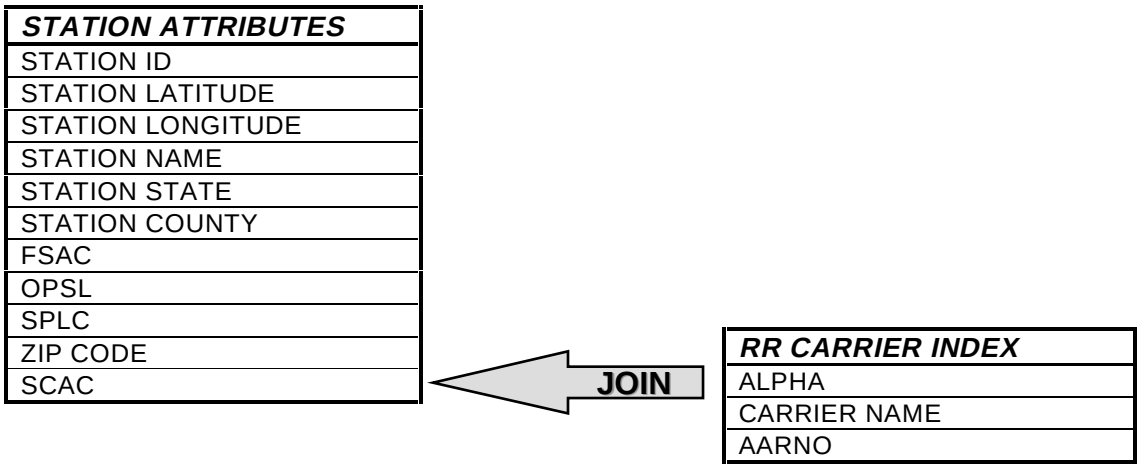
Assemble Station Attributes

After the Alber Leland, Inc. railroad station coordinate data was converted to an Arc/Info point coverage, the station attribute data was converted and joined to it via the *JOINITEM* command using the unique station identification numbers as the key field (depicted below).

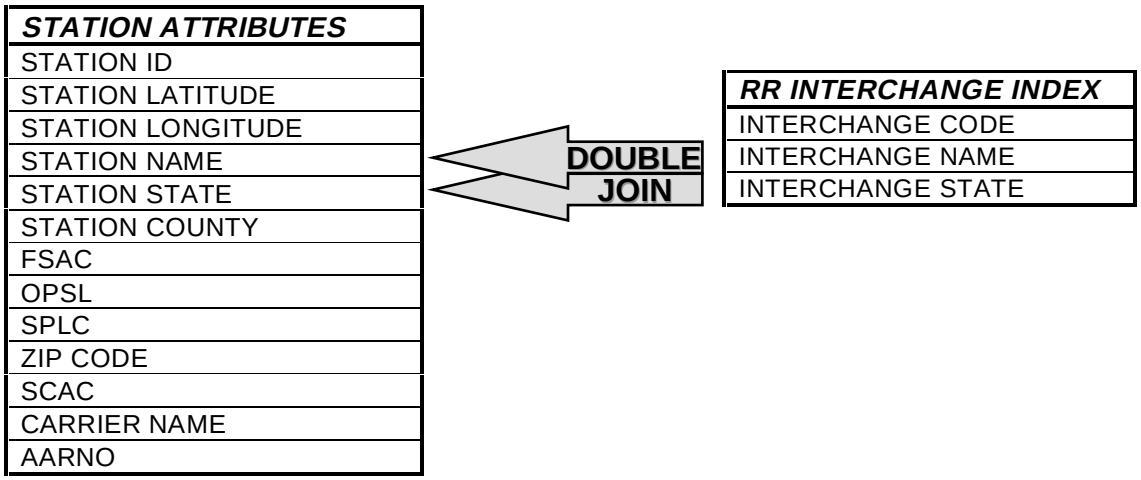


The carrier index was then joined to the station data via railroad alpha codes as shown below.

[2] It was later discovered that this caused a problem with the route identification numbers. The ROUTEID field from the Phase 1 network was defined as a Numeric field with an internal width of 4. The *ARCSHAPE* command forced a decimal point in the output text file, therefore truncating all numbers to three digits. Although the routes had to be processed again, it provided an opportunity to make enhancements to the whole process and its final products.



Next, the *REDEFINE* and *JOINITEM* commands were used to join the interchange index to the station data. The interchange name and state fields were joined with the station name and state fields via a double join as depicted below.



A link was then created between the station data and the railroad network data. Each station was assigned the internal address of the nearest node on the railroad network using the following Arc/Info commands:

BUILD - to create node topology for the rail network,

NEAR - to assign each station the nearest railroad network internal node number (PAREDRAIL#) and the distance between nodes (DISTANCE),

JOINITEM - to join the railroad network node attribute table to obtain the railroad node's user identification number (PAREDRAIL-ID) to be used by the routing program. This also included the railroad network arc the node is associated with (ARC#).

The attributes of the final station data are listed below.

FIELD NAME	*DESCRIPTION*
STATION_ID	Unique Station Identifier
LATITUDE	Station's Latitude in Decimal Degrees
LONGITUDE	Station's Longitude in Decimal Degrees
STAT_NAME	Name of Station
STAT_STATE	State Name of Station
STAT_COUNT	County Name of Station
FSAC	Freight Station Accounting Code,
	Corresponds with Shipment Record's OFSAC, TFSAC *Attributes*
OPSL	Open and Prepaid Station List Number
SPLC	Standard Point Location Code
ZIPCODE	Rating Zip Code
SCAC	Serving Carrier Standard Carrier Alpha Code
CARRIER_NAME	Name of Railroad Carrier
AARNO	American Association of Railroads Number,
	Corresponds with Shipment Record's ORR, RR2, RR3, RR4, TRR *Attributes*
INT_CODE	Alpha Code (interchange name abbreviation),
	Corresponds with Shipment Record's INT1, INT2, INT3, INT4 *Attributes*
PAREDRAIL#	Link to Nearest Railroad Network Node
DISTANCE	Distance to Nearest Railroad Node
ARC#	Internal Identification Number of Associated Railroad Arc
PAREDRAIL-ID	User Identification Number of Nearest Node

Assemble Alternate Station Point Attributes

It was necessary to create an alternate data set to use when a railroad station point was not found in the Alber Leland data set. Therefore, an Arc/Info point data layer was created from railroad network nodes. County FIPS and ownership attributes were added so that origin and destination points could be selected via the customer's shipment record data (ORR, OFIP, TRR, TFIP). The following is a list of main commands used to create the alternate data layer:

NODEPOINT - to create a new point coverage from the nodes in the railroad network,
RELATE - to copy the ARC# values from the rail network nodes, and COMBO_OWN values from the rail network arcs to the new point coverage,
JOINITEM - to join the carrier index attributes to the new point coverage,
IDENTITY - to join the county attributes to the new point coverage,
ALTER - to change field descriptions.

The final alternate data set attributes were:

FIELD NAME	*DESCRIPTION*
RAILPOINTS-ID	Arc/Info User Point Identification Number
Alternate Field Name:	PAREDRAIL-ID
ARC#	Internal Identification Number of Associated Railroad Arc
COMBO_OWN	Ownership Alpha Code - compiled from multiple sources
AARNO	American Association of Railroads Number,
	Corresponds with Shipment Record's ORR, RR2, RR3, RR4, TRR *Attributes*
COUNTY_NAME	Name of County where Point is Located
Previous Field Name:	NAME
STATE_NAME	Name of State where Point is Located
FIPS	Full County FIPS Code,
	Corresponds with Shipment Record's OFIP, TFIP *Attributes*

CREATE ROUTES

Once the data were prepared, the next step was to create the shipment routes. Three AML macros were produced to accomplish this. The main macro (AutoRoute.AML) was created to loop through the shipment records, call the necessary routines to process them (including the external routines ImpedeMany.AML and RouteBills.AML), and create the output files. Each AML is discussed further below.

Computer processing time was extensive due to the tremendous amount of data and the complexity of calculations. Therefore, the GIS Team divided the shipment records into batches and used as many central processing units and hard drives as possible in parallel. Originally, 12 CPUs were used with 14 different hard drives, but the maximum number of Arc/Info Network module licenses was 5, so the number of batches running simultaneously were reduced. Only 5 to 7 of the Sun Ultra workstations were used at one time on as many local hard drives as possible. Even after much of the GIS Team's computer network was upgraded to 100 megabyte Ethernet lines and two 9 megabyte hard drives were purchased by the Navigation Team, the final round of processing took approximately 4 weeks to process the 75,000 shipment records.

Main AML

The main AML macro used CURSOR commands to loop through the customer's shipment records, one shipment leg at a time. For each leg of a shipment, an attempt was made to find an originating and terminating node based on the following logic.

If the shipment route does not have any interchange points (only one leg):

- Use the shipment record originating and terminating FSAC codes and railroad owner AAR numbers (OFSAC, ORR, TFSAC and TRR fields) to find matching origin and destination points in the railroad station file (via the FSAC and AARNO fields). Store the identification number of the nearest nodes on the railroad network (PAREDRAIL-ID fields) in two variables, namely *from_node* and *to_node*, to pass on to the routing AML.

- If an origin or destination point cannot be found, use the shipment record county FIPS code (OFIP or TFIP) to find a matching point in the alternate station file for the current owner (ORR or TRR).
- If an origin or destination point still cannot be found, then use the shipment record county FIPS code (OFIP or TFIP) to find a point on the network within the county (via the alternate station file), regardless of the owner.
- If no match can be established[3], write the shipment record number to an error file.

If the shipment route has interchange points:

- For the first leg of the route, use the shipment record originating FSAC code and railroad owner abbreviation (OFSAC, ORR fields) to find a matching origin point in the railroad station file. If no match was found in the station file, then use the alternate station file as stated above. If no match can be established, write the shipment record number and leg number to an error file. Otherwise, store the identification number of the nearest node on the railroad network (PAREDRAIL-ID field) in a variable (*from_node*) to pass on to the routing AML.
- Find an interchange point by matching the shipment record interchange code and railroad owner AAR number (for example, INT1 and RR2 fields) to a point in the railroad station file (via the INT_CODE and AARNO fields). If an interchange point cannot be found for that owner, then find a matching point with the same interchange abbreviation, regardless of the owner. If no match can be established, write the shipment record number and leg number to an error file. Otherwise, store the node identification number in the *to_node* variable.
- For each subsequent leg, copy the *to_node* value to the *from_node* variable and find the next interchange point (such as INT2, RR3) until reaching the last leg.
- For the last leg of the route, use the shipment record terminating FSAC code (TFSAC) and railroad owner abbreviation (TRR) to find a matching destination point in the railroad station file. If no match was found in the station file, then use the alternate station file as stated above. If no match can be established, write the shipment record number and leg number to an error file. Otherwise, store the identification number in the *to_node* variable to pass on to the routing AML.

Once the *to_node* and *from_node* variables were established, and were not equal to eachother, then the impedance values for the current owner were set on the network by calling the external impedance routine (only if the ownership had changed since the previous shipment leg). Afterward, the route was created for that leg via the external routing routine, and output was generated.

Impedance AML

The impedance AML macro set impedance values on the railroad network by assigning numbers to each arc's IMPEDE field via Arc/Info's Tables module. Since the routing algorithm used the shortest path method, impedance values were based on arc length (i.e., travel distance). The higher the number, the more difficult it was to travel across the arc (i.e., portion of track). The *SELECT*, *CALCULATE*, *RESELECT*, and *ASELECT* commands were used to:

[3] Canadian legs of shipment routes were not processed.

- Select the arcs belonging to the current owner, **or** if the current owner was associated with a group of owners that share tracks, then select the arcs belonging to the whole group. (Only the six most important routing partnerships were used). Set the IMPEDE field of each selected arc to its arc length.
- Select the arcs of all the other owners. Set the impedance value of each selected arc to twice the length of the arc.
- Select all unknown owners' arcs. Set the impedance value of each selected arc to three times the length of the arc.

The impedance values were set so that the routing algorithm would first choose railroad tracks of the current owner or group of owners, then choose tracks from the other owners, and finally, choose tracks of unknown ownership. Therefore, abandoned tracks were the least likely to be used.

Routing AML

The routing AML macro created shipment routes by using Arc/Info's Network commands via the ArcPlot module. The following commands were used:

NETCOVER	- to specify the PAREDRAIL network file to be used by the Network commands to create and store the route system tables,
IMPEDANCE	- to specify the IMPEDE field to be used by the Network commands for network impedance values,
PATH	- to find the minimum path between the *from_node* and the *to_node* for each leg of a shipment.

The AML also contained ArcPlot drawing commands (*MAPEXTENT*, *ARCLINES*, *ROUTELINES*) for visually checking the route systems as they were created. Since the drawing time slowed the processing time, only the first few routes were verified for each batch, then the drawing commands were turned off until deemed necessary again.

GENERATE OUTPUT

After calling the routing AML, the main AML used the Tables *SELECT* command with the AML *SHOW* function to check if the route had indeed been created. If so, the route attribute table (RAT) and associated section (SEC) files were *EXPORT*ed via the *INFO* option[4]. If not, a message was written to an error file.

The *FREQUENCY* command was then used to create a non-duplicate list of all the route identification numbers (ROUTEID values) of arcs that the shipment leg had traveled across. The Tables *SELECT*, *RESELECT*, and *UNLOAD* commands were used to write out all nonzero ROUTEIDs with their associated UNIQUE number into a text file in columnar format. The *DROPFEATURES* command was then used to delete the RAT and SEC files because of the

[4] It was later discovered that the exported route systems were viewable in ArcPlot, but not ArcView, since they were no longer attached to the original railroad network file.

Arc/Info limit on the number of Info files[5]. Therefore, an output text file was created for every leg of a shipment that contained nonzero ROUTEIDs.

Multiple error files and status reports were also created while processing the shipment records. Information from these files was used to re-process shipment legs when possible.

After all the records were processed, UNIX 'cat' commands were used to concatenate all of the ROUTEID output files into one large file. It was *LOAD*ed back into Tables and *SORT*ed by UNIQUE number, and *UNLOAD*ed again to a text file and shipped to the customer.

CONCLUSION

The initial objective of this phase of the railroad capacity project was to develop a GIS application to simulate routing railroad shipments and produce a list of specialized route identification numbers for the customer in less than two months. The GIS Team accepted the proposed project with the mutual understanding that this was a high risk research and development project. (It was not known at the onset if the desired product was feasible.) However, the initial GIS application was developed in less than two months, and the project would have been completed on schedule had it not been for the large amounts of time necessary to process the data. In spite of this, the end product was achieved and the process also pioneered the development of other beneficial products.

The following output files were created for Phase 2 of the railroad capacity project:

1). Text file containing attribute information for arcs considered important for calculating the line-haul capacity of selected railways:

FIELD NAME	*DESCRIPTION*
UNIQUE	Unique Shipment Identifier Assigned by Dr. Mark Burton from the customer shipment records
ROUTEID	Dr. Mark Burton's Route Identification Number from the railroad network arcs

2). Exported Arc/Info route system files
3). Error text files
4). Status reports

Other products created for this project were:

1). 1:100,000 scale railroad network with specialized attributes in Arc/Info format
2). Railroad stations in Arc/Info format
3). AML software for routing railroad shipments
4). Color plots of routes deemed to be within the top 100 rail capacity indicators

In conclusion, similar future projects should be given ample time and funding for developing and implementing more efficient routing methods, as well as consulting experts in the GIS Transportation business.

[5] It was later discovered that this could be avoided by using the *NETCOVER* and *PATH* commands differently.

GIS PROCESS OVERVIEW
for the
RAILROAD LINE-HAUL CAPACITY PROJECT

Geographic Information Systems Group
Engineering Services
Tennessee Valley Authority
Norris, Tennessee

May 1997

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LIST OF ABBREVIATIONS

AML - Arc Macro Language

BTS - Bureau of Transportation Statistics

DEM - Digital Elevation Model

FRA - Federal Railroad Administration

FTP - File Transfer Protocol

GIS - Geographic Information System

NTAD - National Transportation Atlas Databases

ORNL - Oak Ridge National Laboratory

USGS - United States Geological Survey

INTRODUCTION

Members of the TVA Norris GIS Group accepted a project from the TVA Navigation Team in February 1997 to assist them in determining the line haul capacity of selected railroad lines in the United States. The objective of the GIS phase of the project was to merge *attribute* information from multiple transportation and topographic data sources. This was a pilot project to be accomplished in the least amount of time and finances possible — not to provide a topologically correct routing network.

The primary attributes requested by the customer were:

- specialized route identification numbers
- railroad ownership names / abbreviations
- USGS Digital Line Graph major and minor attribute codes
- density categories
- signaling system types
- slope information
- railroad grade crossing identification numbers and street names

A specialized route identification number was manually added by an undergraduate student interning with the TVA Navigation Team. The railroad ownership names and major and minor attribute codes were taken from a 1:100,000 scale railroad network provided by the Bureau of Transportation Statistics. The density and signaling information was taken from a 1:2,000,000 scale railroad network also provided by BTS. Slope information was calculated from USGS Digital Elevation Model data. Railroad grade crossing data were acquired from the Oak Ridge National Laboratory.

Because of the lack of common attribute information (no key fields), it was necessary to use a Geographic Information System to *spatially* join each database together. For instance, the 1:2,000,000 scale network arc attributes were joined to the 1:100,000 scale network arc attributes based on their proximity. Figure 1 and Tables 1, 2, and 3 illustrate the process of joining an arc from the 1:2,000,000 scale network to an arc from the 1:100,000 scale network. An example arc (Arc #1) from the 1:100,000 scale network is shown in Figure 1 and its attributes in Table 1. An example arc (Arc #99) from the 1:2,000,000 scale network is also shown in Figure 1 and its attributes are depicted in Table 2. In this example, Arc #99 is the arc nearest to Arc #1, therefore its attributes are appended to the Arc #1 attributes. The resulting attribute table is shown in Table 3.

Members of the GIS Group used this type of process to merge all of the initial databases together to produce the final output for the project (Figure 2). The GIS Group used Arc / Info® 7.0.4 and ArcView® 2.1 running on a network of Sun Ultra Workstations. The final digital data files were transferred to the customer on a network Pentium PC.

Unlike most GIS tasks, the final products of this pilot project were listings of attribute information only. In most GIS transportation applications, the primary objective is to produce a topologically correct network at a maintained scale. In this case, the emphasis was not on the connectivity of the geographic data, but on the amount of time taken to merge the attribute

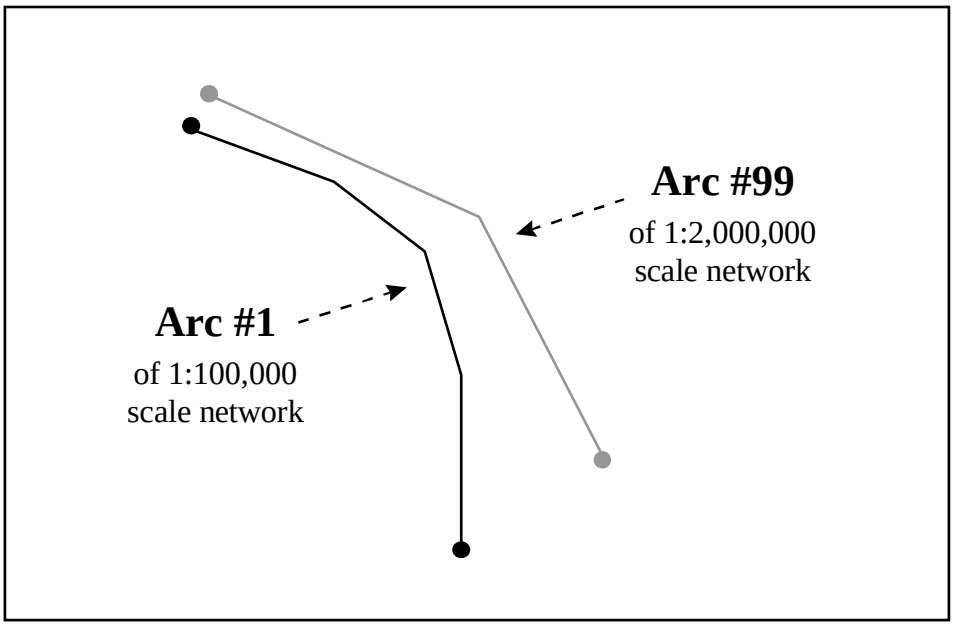

Figure 1. Spatail Join Example

Arc100k #	Route #	Owner	Major Code	Minor Code
1	2462	WC	180	208

Table 1. Example 1:100,000 Scale Railroad Network Attributes

Arc2m #	Density	Signaling
99	1.0	Manual

Table 2. Example 1:2,000,000 Scale Railroad Network Attributes

Arc100k #	Route #	Owner	Major Code	Minor Code	Arc2m #	Density	Signaling
1	2462	WC	180	208	99	1.0	Manual

Table 3. Resulting Railroad Join Attributes

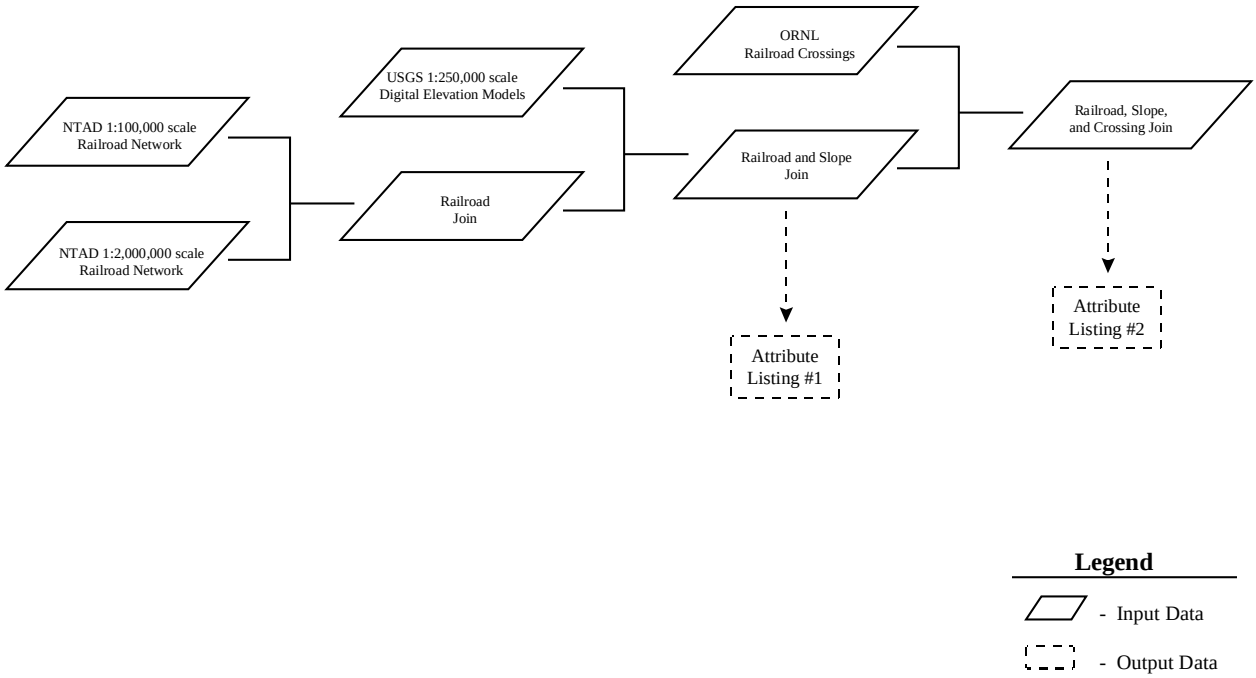

Figure 2. Multiple Joining of Input Data to Produce the Final Output Data

information together. Therefore, although the 1:100,000 scale railroad network did not maintain connectivity, it was chosen as the base network for the project since the 1:2,000,000 scale network did not contain secondary routes. For the next phase of the project, however, a topologically correct 1:100,000 scale railroad network should be available.

INPUT DATA

There were four main input data sets used for the project:

1). 1:100,000 scale railroad network taken from the 1995 National Transportation Atlas Databases (NTAD) compact disc. The CD was ordered via the Department of Transportation's Bureau of Transportation Statistics website: **http://www.bts.gov**
C code and ARC Macro Language (AML) routines were written to import the data into Arc/Info®.

2). 1:2,000,000 scale railroad network taken from the 1996 National Transportation Atlas Databases (NTAD) compact disc. The CD was ordered via the Department of Transportation's Bureau of Transportation Statistics website: **http://www.bts.gov**
The data was imported into Arc/Info® using an AML macro downloaded from the internet (btsarc.aml) and a user written AML macro routine.

3). 1:250,000 Digital Elevation Models downloaded from the United States Geological Survey website: **http://edcwww.cr.usgs.gov/glis/hyper/guide/1_dgr_demfig/index1m.html**
The DEMs were downloaded from the internet and copied to recordable compact disks. Another set of CDs was also made which contained only those DEMs thought to be necessary for the project. AML macros were written to copy each of these DEMs from CD to a disk drive, uncompress them, and use the Arc/Info® DEMLATTICE command to convert them to an Arc/Info® LATTICE.

4). Railroad grade crossing data received from Bruce Peterson of the Oak Ridge National Laboratory via FTP. The railroad crossing data were imported into Arc/Info® manually using Info™ commands.

In addition, the Navigation Team student used an Arc/Info® coverage of the 1995 NTAD Place Names provided by the Norris GIS Group, and a list of railroad routes along with a PC Rail© network provided by the customer.

PROCESS OVERVIEW

A simplified graphical description of the GIS process is shown in Figure 3. Crucial network routes were first extracted from the NTAD 1:100,000 scale network to create a new, reduced network. Attributes from the NTAD 1:2,000,000 scale network were then joined to the new 'crucial route network'. Slope attributes were calculated for each arc in the new network and an output listing was created which contained all attribute information for every arc. Afterwards, the network arc attributes were joined to the railroad crossing point attributes and another output listing was created. Both output listings were then delivered to the customer.

Selecting Crucial Routes

A list of crucial railroad routes was defined and provided by the customer along with a PC Rail© railroad network to the Navigation Team undergraduate intern. For each route on the list provided, the intern used the origin, destination, and ownership names to visually locate the route on the PC Rail© network on a desktop PC. A Sun workstation running Arc/Info® was used to visually locate the identical route on the 1:100,000 scale network. The arcs for the route were <u>select</u>ed[1] in ArcEdit and <u>put</u> into (appended to) a new data layer. A unique identification number was manually assigned to each route via the listing received from the customer. The final Arc/Info® output coverage containing the crucial routes was then given to the Norris GIS Group. Because of some of the following problems, not all routes were matched.

1. The two networks were not displayed in the same projection. The 1:100,000 scale network was in a Geographic coordinate system (latitude and longitude in decimal degrees) and the PC Rail© network projection was unknown.
2. There were discrepancies amongst railroad ownership names.
3. The topology differed between the two networks.

[1] Arc/Info® commands are underlined

GIS PROCESS OVERVIEW

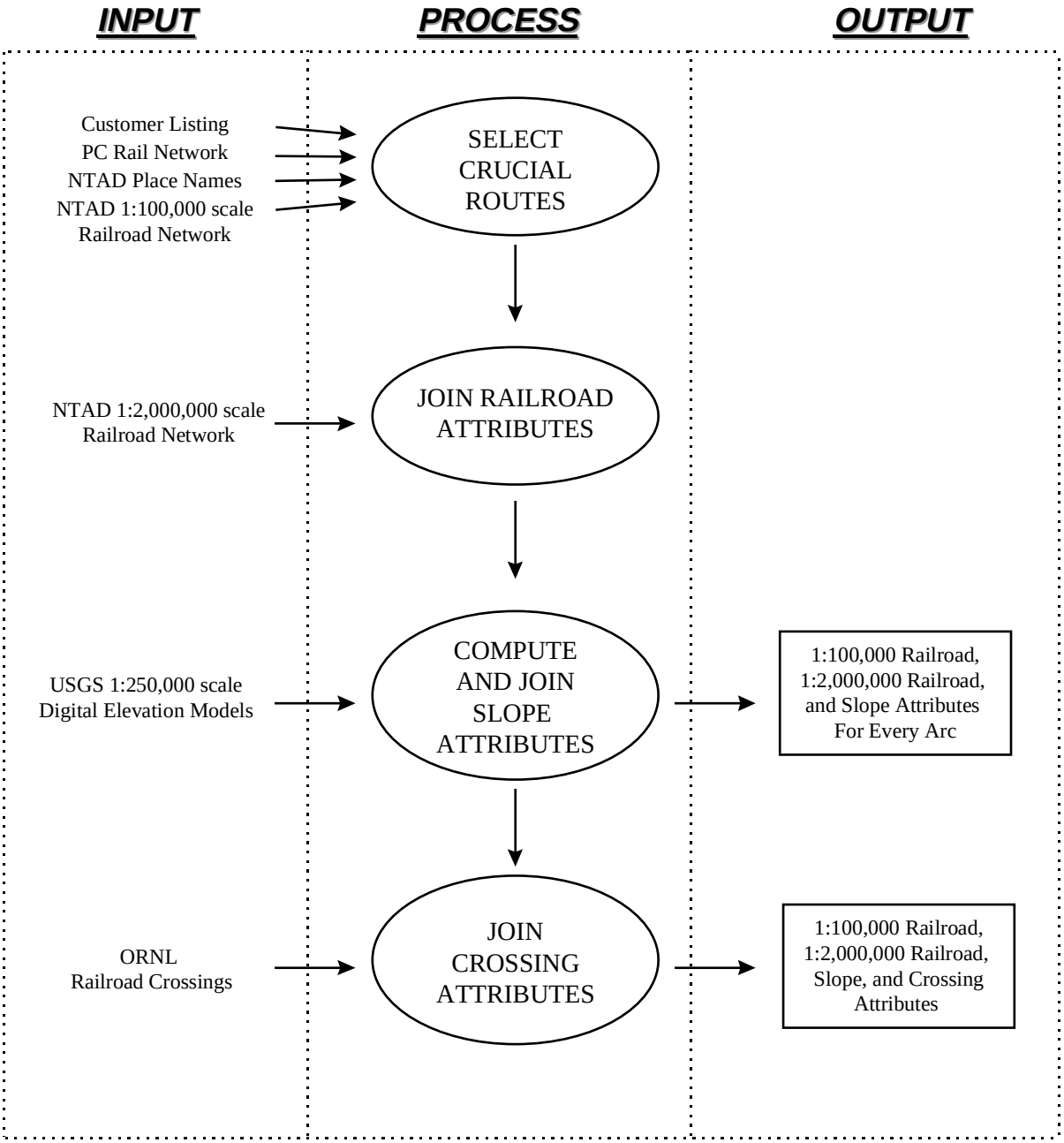

Figure 3. GIS Process Overview

Joining Railroad Network Attributes

After receiving the crucial route network, the Norris GIS Group joined the 1:2,000,000 scale NTAD railroad network attributes to it through a two step procedure. First, the following Arc/Info® commands were used to automate matching the attributes:

- ARCLABEL - to create a coverage containing the midpoint of each arc in the crucial route network.
- BUILD - to build the point topology for the coverage.
- NEAR - to place a pointer in the midpoint coverage to the nearest 1:2,000,000 scale arc (within a specified tolerance).
- JOINITEM - to join the 1:2,000,000 attributes to the midpoint coverage.
- JOINITEM - to join the midpoint coverage attributes (now containing the 1:2,000,000 attributes) back to the 1:100,000 scale crucial route network.

The primary challenge encountered in the first step was to determine the tolerance level setting so that as many attributes as possible from the 1:2,000,000 scale NTAD network could be joined without creating incorrect matches at intersections or near parallel lines. The poor topology (lack of connectivity and duplicate arcs) of the original NTAD 1:100,000 scale network was also a factor. The Arc/Info® CLEAN command was used in an attempt to lessen the problem.

After finishing the automated procedure, the second step was to make a visual pass of the network and manually correct any problems, i.e. verify that the correct 1:2,000,000 scale attributes had been joined. The crucial route network was divided into two separate coverages so that two GIS technicians could correct it simultaneously. AML macros and menus were written to aid the technicians in transferring attributes. Attributes for arcs in which a match could not be determined were set to zero. Problems encountered were mainly due to the differing topology and scale between the 1:100,000 scale crucial route network and the 1:2,000,000 scale NTAD network. The crucial route network was re-appended upon completion of the manual corrections.

Computing and Joining Slope Attributes

The next phase of the project was to compute the slope for each arc in the crucial route network and join the slope attributes to the network. As mentioned before, AML macros were used to copy each DEM from CD to a disk drive, uncompress them, and convert them to an Arc/Info® LATTICE. The slope (in percent) was then computed for each LATTICE using the Arc/Info® GRID function SLOPE. These slope LATTICEs were written to a set of 8 recordable compact disks.

ArcView® was used to review each file on the CDs for anomalies. Many of the files had 'streaks' which originated from the USGS data collection procedures, but they were not corrected (filtered) as part of the pilot project because of time constraints. There were also two anomalous rectangular areas originating from the downloaded DEMs. One was near Texas in DEM files: Brownfield-E, Clovis-E, Lubbock-W, and Plainview-W. The other was in the Norfolk-W file. Therefore, slope was not computed for network data overlaying these areas.

Arc/Info® was used to extract slope data from multiple points along the crucial route network. The following Arc/Info® commands were used:

- PROJECT - to place the network in the same coordinate space as the slope LATTICE files. (Also, the USGS quad map boundaries and names were projected so they could be used as background data).
- DENSIFYARC - to place a vertex at least every 90 meters along the crucial route network (since the slope data was based on 90 meter DEM data).
- ARCPOINT - to create a point coverage from all of the nodes and vertices contained in the crucial route network.
- BUILD - to build point topology for the new point coverage.
- SELECT & PUT - to manually divided the point coverage into smaller coverages to correspond with each DEM slope LATTICE. (Because of the large amount of data, it was necessary to process the slope data one file at a time.)
- LATTICESPOT - to extract slope values for each point along the crucial route network, therefore providing a slope value at least every 90 meters. This command was used in a series of AMLs which cycled through each point coverage alphabetically and extracted the slope data values from the set of 8 CDs.

The Tables module of Arc/Info® was used to reselect all data that did not have undefined slope values and unload them into ASCII text format files. UNIX commands were used to concatenate all of these files into one large file. The file was imported into ArcView® and the Summary Table Definition function was used to compute the minimum, maximum, variance, and average slope for each arc identification number. This tabular data was exported as an Info™ file and the Arc/Info® JOINITEM command was used to permanently join the slope information to the crucial route network. ArcView® was used to sort the network by arc ID number, add a flag for determining railroad crossing availability, and export all the arc information in ASCII comma-delimited and also dBASE format.

During this phase of the project a few files had to be reprocessed (mostly because of incorrect file names), but the main challenge was managing disk space. The GIS Group used one 4 gigabyte hard drive and four 2 gigabyte hard drives, as well as a CD writer, two CD readers, and an 8 mm tape drive.

Joining Railroad Crossing Attributes

Many of the railroad crossing data points received from ORNL did not have latitude and longitude information and, consequently, were deleted. The crucial route network attributes were then joined to the existing railroad crossing data points using the following Arc/Info® commands:

- NEAR - to place a pointer in the railroad crossing coverage to the nearest crucial route network arc (within a very small tolerance).
- JOINITEM - to join the crucial route network attributes to the railroad crossing coverage.

ArcView® was used to sort the railroad crossings by their associated arc ID number and export all the point information in ASCII comma-delimited and also dBASE format.

OUTPUT DATA

The following data were produced from the pilot project:

- 2 CDs containing USGS DEMs in GNU Zip compression format
- 2 CDs with pilot project DEMs in GNU Zip compression format
- 8 CDs with slope data for the project in Arc/Info® LATTICE format
- 9 sets of 8mm archival tapes containing pilot project data
- 2 final output files:

  1). A file in dBASE format containing attribute information from all the possible arcs considered important for calculating the line haul capacity of selected railways. See Appendix A for attribute descriptions.

  2). A file in dBASE format containing attribute information from all the railroad grade crossing points located near crucial route arcs and the attribute information from those arcs. See Appendix B for attribute descriptions.

The customer imported the two final output files into SAS, deleted any unnecessary fields, and merged the data together with other FRA data to perform the final analyses. The customer was made aware that the final output contained 78 arcs without slope data attributes. Slope attributes had not been computed for these arcs because they overlayed the anomalous DEM areas mentioned earlier. (These arcs comprised seven partial routes and one whole route.) There were also 687 duplicate arc ID numbers. Unfortunately, these had been created from the Arc/Info® CLEAN command which was used to clean up the poor topology from the base network. This problem, however, was not a serious detriment to the customer's needs since his main analysis was route-based, not arc-based.

FINAL REMARKS

There were three major difficulties in accomplishing this pilot project:

1) the lack of a topologically correct railroad network which included secondary routes,
2) the challenge of utilizing given GIS tools to accomplish an unconventional task, and
3) the lack of contiguous disk space.

As technology improves, the integrity of input data, the capability of software packages, and the speed and capacity of computer hardware will increase, thus, making a project such as this a much simpler task. Even so, we will continue to push our resources to their fullest capacity to try to solve more complicated problems.

APPENDIX
A

Output File #1 Attribute Descriptions

OUTPUT FILE #1 ATTRIBUTE DESCRIPTIONS

1: 100,000 Railroad Network Attributes

MARKFINAL#: Record number generated by Arc/Info®

MARKFINAL-ID: Arc ID number taken from the original 1995 NTAD 1:100,000 scale railroad network

[2]FROMNODE: Node ID in rail_100.pnt

[2]TONODE: Node ID in rail_100.pnt

[2]LINKID: Unique identification number

[2]LINKLEN: Link length

[2]DIRECTION: Always 0

[2]MAJORATT: Major attribute code from USGS digital line graphs

- 180 Transportation systems - railroads
- 181 Railroads: minor attribute indicates number of tracks
- 188 Best estimate of position or classification
- 189 Coincident feature

[2]MINORATT: Minor attribute code from USGS digital line graphs

- 0001 Bridge abutment
- 0002 Tunnel portal
- 0007 Drawbridge
- 0100 Void area
- 0201 Railroad
- 0202 Railroad in street or road
- 0204 Carline
- 0205 Cog railroad, incline railway, logging tram
- 0207 Ferry crossing
- 0208 Railroad siding
- 0209 Perimeter or limit of yard
- 0210 Arbitrary line extension
- 0211 Closure line
- 0400 Railroad station, perimeter of station
- 0401 Turntable
- 0402 Roundhouse
- 0600 Historical
- 0601 In tunnel
- 0602 Overpassing, on bridge
- 0603 Abandoned
- 0604 Dismantled
- 0605 Underpassing
- 0606 Narrow gauge
- 0607 In snowshed or under structure
- 0608 Under construction
- 0609 Elevated
- 0610 Rapid transit
- 0611 On drawbridge

[2] Taken from the 1995 NTAD rail_100.lin file. Refer to the CDs rail_100.txt file for further description.

	0612 Private
	0613 U.S. Government
	0614 Juxtaposition
	0000 Photorevised feature
	Note: If major attribute is 181 then minor attribute is number of tracks.
[2]OWNER:	Alphanumeric identifier of the owning railroad
ROUTEID:	Mark Burton's route ID number added by Cathy Adams

1: 2 million Railroad Network Attributes

NRAIL2M#:	Record number generated by Arc/Info®
NRAIL2M-ID:	Arc ID number taken from the original 1996 NTAD 1:2,000,000 scale railroad network
[3]LRECTYPE:	Link record type: always 'L'
[3]LVERSION:	Link file version number
[3]LREVISION:	Link record revision number
[3]LMODDATE:	Link record modification date
[3]LINKID2M:	Unique sequential line identification
[3]FEATUREID:	Unique line identification
[3]ANODE:	Node identification for the beginning node of the line
[3]BNODE:	Node identification for the ending node of the line
[3]DESCRIPT:	Name or identification for the line feature
[3]STFIPS1:	Primary State FIPS Code
[3]STFIPS2:	Secondary State FIPS Code
[4]RECTYPE:	Text record type: Always 'T'
[4]VERSION:	Text file version number
[4]REVISION:	Text record revision number
[4]MODDATE:	Text record modification date
[4]OVERLAY:	Country marker
[4]RROWN1:	First railroad owner name
[4]RROWN2:	Second railroad owner name
[4]RROWN3:	Third railroad owner name
[4]TR1:	First railroad having trackage rights
[4]TR2:	Second railroad having trackage rights
[4]TR3:	Third railroad having trackage rights
[4]TR4:	Fourth railroad having trackage rights
[4]TR5:	Fifth railroad having trackage rights
[4]TR6:	Sixth railroad having trackage rights
[4]TR7:	Seventh railroad having trackage rights
[4]TR8:	Eighth railroad having trackage rights
[4]TR9:	Ninth railroad having trackage rights
[4]SSRR:	Subsidiary railroad

[3] Taken from the 1996 NTAD rail2m.lnk file. Refer to the CDs rail_2m.met file for further description.

[4] Taken from the 1996 NTAD rail2m.tl1 file. Refer to the CDs rail_2m.met file for further description.

[4]PRR1:	First previous Railroad owner
[4]PRR2:	Second previous railroad owner
[4]ABDN:	Abandoned flag
[4]PASS:	Type of passenger rail flag
[4]MIL:	Military importance flag
[4]STATE:	Postal Code
[4]USGS_REG:	USGS Region Code
[4]FRA_REG:	FRA Region Code
[4]DENSITY:	Density Category
[4]RR_CLS:	Railroad classification
[4]SIGNALS:	Type of signaling system
[4]ABDYR:	Abandonment Year
[4]STFIPS:	State FIPS Code

Slope Attributes Generated from USGS DEM Data

COUNT:	Number of slope sample points for this arc
MIN_SLOPE:	Slope minimum for this arc (percent rise)
MAX_SLOPE:	Slope maximum for this arc (percent rise)
VAR_SLOPE:	Slope variance for this arc
AVE_SLOPE:	Slope average for this arc

Railroad Crossing Attributes

XING: Flag for determining if this arc has associated railroad crossing data:
"1" - means associated railroad crossing data exists,
otherwise the field is blank.

APPENDIX
B

Output File #2 Attribute Descriptions

OUTPUT FILE #2 ATTRIBUTE DESCRIPTIONS

Railroad Crossing Attributes

MARKXINGS#: Record number generated by Arc/Info®
MARKXINGS-ID: Arc/Info® Point ID number
[5]GCIS_ID: Railroad Crossing ID number (same as FRA ID)
[5]X_DD: Longitude of the railroad crossing
[5]Y_DD: Latitude of the railroad crossing
[5]SOURCE: "V" - means located by Paul Cheng in TIGER with a street name or railroad match
"M" (by milepoint) - interpolated between V's
[5]RR: Ownership name abbreviation for the railroad crossing
[5]DIVISION: Division
[5]SUB_BRANCH: Sub/branch
[5]MP: Milepoint
[5]STREET: Street name of the railroad grade crossing

1: 100,000 Railroad Network Attributes

MARKFINAL#: Record number generated by Arc/Info®
MARKFINAL-ID: Arc ID number taken from the original 1995 NTAD 1:100,000 scale rail network
[6]FROMNODE: Node ID in rail_100.pnt
[6]TONODE: Node ID in rail_100.pnt
[6]LINKID: Unique identification number
[6]LINKLEN: Link ID number
[6]DIRECTION: Always 0
[6]MAJORATT: Major attribute code from USGS digital line graphs

180	Transportation systems - railroads
181	Railroads: minor attribute indicates number of tracks
188	Best estimate of position or classification
189	Coincident feature

[6]MINORATT: Minor attribute code from USGS digital line graphs

0001	Bridge abutment
0002	Tunnel portal
0007	Drawbridge
0100	Void area
0201	Railroad
0202	Railroad in street or road
0204	Carline
0205	Cog railroad, incline railway, logging tram
0207	Ferry crossing

---

[5] Taken from data provided by Bruce Peterson of the Oak Ridge National Laboratory.

[6] Taken from the 1995 NTAD rail_100.lin file. Refer to the CDs rail_100.txt file for further description.

0208	Railroad siding
0209	Perimeter or limit of yard
0210	Arbitrary line extension
0211	Closure line
0400	Railroad station, perimeter of station
0401	Turntable
0402	Roundhouse
0600	Historical
0601	In tunnel
0602	Overpassing, on bridge
0603	Abandoned
0604	Dismantled
0605	Underpassing
0606	Narrow gauge
0607	In snowshed or under structure
0608	Under construction
0609	Elevated
0610	Rapid transit
0611	On drawbridge
0612	Private
0613	U.S. Government
0614	Juxtaposition
0000	Photorevised feature

Note: If major attribute is 181 then minor attribute is number of tracks.

[6]OWNER: Alphanumeric identifier of the owning railroad

ROUTEID: Mark Burton's route ID number added by Cathy Adams

1: 2 million Railroad Network Attributes

NRAIL2M#: Record number generated by Arc/Info®

NRAIL2M-ID: Arc ID number taken from the original 1996 NTAD 1:2,000,000 scale railroad network

[7]LRECTYPE: Link record type: always 'L'

[7]LVERSION: Link file version number

[7]LREVISION: Link record revision number

[7]LMODDATE: Link record modification date

[7]LINKID2M: Unique sequential line identification

[7]FEATUREID: Unique line identification

[7]ANODE: Node identification for the beginning node of the line

[7]BNODE: Node identification for the ending node of the line

[7]DESCRIPT: Name or identification for the line feature

[7]STFIPS1: Primary State FIPS Code

[7]STFIPS2: Secondary State FIPS Code

[7] Taken from the 1996 NTAD rail2m.lnk file. Refer to the CDs rail_2m.met file for further description.

[8]RECTYPE:	Text record type: Always 'T'
[8]VERSION:	Text file version number
[8]REVISION:	Text record revision number
[8]MODDATE:	Text record modification date
[8]OVERLAY:	Country marker
[8]RROWN1:	First railroad owner name
[8]RROWN2:	Second railroad owner name
[8]RROWN3:	Third railroad owner name
[8]TR1:	First railroad having trackage rights
[8]TR2:	Second railroad having trackage rights
[8]TR3:	Third railroad having trackage rights
[8]TR4:	Fourth railroad having trackage rights
[8]TR5:	Fifth railroad having trackage rights
[8]TR6:	Sixth railroad having trackage rights
[8]TR7:	Seventh railroad having trackage rights
[8]TR8:	Eighth railroad having trackage rights
[8]TR9:	Ninth railroad having trackage rights
[8]SSRR:	Subsidiary railroad
[8]PRR1:	First previous Railroad owner
[8]PRR2:	Second previous railroad owner
[8]ABDN:	Abandoned flag
[8]PASS:	Type of passenger rail flag
[8]MIL:	Military importance flag
[8]STATE:	Postal Code
[8]USGS_REG:	USGS Region Code
[8]FRA_REG:	FRA Region Code
[8]DENSITY:	Density Category
[8]RR_CLS:	Railroad classification
[8]SIGNALS:	Type of signaling system
[8]ABDYR:	Abandonment Year
[8]STFIPS:	State FIPS Code

Slope Attributes Generated from USGS DEM Data

COUNT:	Number of slope sample points for this arc
MIN_SLOPE:	Slope minimum for this arc (percent rise)
MAX_SLOPE:	Slope maximum for this arc (percent rise)
VAR_SLOPE:	Slope variance for this arc
AVE_SLOPE:	Slope average for this arc

[8] Taken from the 1996 NTAD rail2m.tl1 file. Refer to the CDs rail_2m.met file for further description.

COSTS

Summary	Track $/Mile	Track $/Ft	Base Case Turnout cost
Siding Case	$383,730	$73	$98,768
Light density case	$411,231	$78	$92,768
Medium density case	$457,013	$87	$98,768
Heavy haul case	$489,841	$93	$119,691
	$809,110		

	Existing ROW Incr. $/Mile	New ROW $/Mile
Flat Terrain		$119,262
Rolling Terrain	$163,612	$786,241
Mountainous Terrain	$546,532	$3,795,915

COSTS

Control point cost

$129,290

$129,290

$129,290

$129,290

ROUTE CHARACTERISTICS	
State of Operation	In-Region
Average Timetable Speed	36.92
Siding Size	0.41
Percent ABS	0.24
Percent CTC	0.24
Route Length	51.61
Daily Switch Movements	2.11829
Average Train Length	74.81
Train Speed Ratio (Minimum / Timetable	0.38
Number of Mainline Tracks	1.20
Proportion of Trackage with Sidings	0.11
Carloads Per-Year Supported	177,050

INFRASTRUCTURE IMPROVEMENT	COST
Install CTC throughout Route	23,765,394
Install (3) 10,000’ Sidings	2,782,608
TOTAL	26,548,002

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	121,833
Percentage of Original	168.81%
In Ton-Miles (100% ERR)	301,805,939
Incremental Per-Ton-Mile Capacity Cost	0.00440

44262.589

74720.7272

ROUTE CHARACTERISTICS	
State of Operation	Missouri
Average Timetable Speed	54.35
Siding Size	0.41
Percent ABS	0
Percent CTC	1
Route Length	58.472
Daily Switch Movements	2.11829
Average Train Length	23.092
Train Speed Ratio (Minimum / Timetable	0.62957
Number of Mainline Tracks	1.2021
Proportion of Trackage with Sidings	0.12409
Carloads Per-Year Supported	524,729

INFRASTRUCTURE IMPROVEMENT	COST
Construct 2nd Main Track to Heavy-Haul Standards	53,099,008
Install (2) 10,000’ Sidings	1,855,072
TOTAL	54,954,080

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	397,928
Percentage of Original	175.83%
In Ton-Miles (100% ERR)	1,116,847,116
Incremental Per-Ton-Mile Capacity Cost	0.00246

131182.28

230664.29

ROUTE CHARACTERISTICS	
State of Operation	Illinois / Iowa
Average Timetable Speed	16.28
Siding Size	2.92
Percent ABS	0
Percent CTC	0.8
Route Length	28.88
Daily Switch Movements	2.11829
Average Train Length	48.119
Train Speed Ratio (Minimum / Timetable	0.25597
Number of Mainline Tracks	0.38129
Proportion of Trackage with Sidings	0.07711
Carloads Per-Year Supported	158,512

INFRASTRUCTURE IMPROVEMENT	COST
Rebuild Track to Medium Density Standards	17,923,650
Install (2) 10,000’ Sidings	1,855,072
Upgrade Remaining Track Signals to CTC	3,978,480
TOTAL	21,902,130

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	218,514
Percentage of Original	237.85%
In Ton-Miles (100% ERR)	302,912,747
Incremental Per-Ton-Mile Capacity Cost	0.00362

39628.1167

94256.5987

ROUTE CHARACTERISTICS	
State of Operation	Illinois
Average Timetable Speed	26.66
Siding Size	0.39
Percent ABS	0
Percent CTC	0
Route Length	46.47
Daily Switch Movements	0.97222
Average Train Length	17.867
Train Speed Ratio (Minimum / Timetable	0.3456
Number of Mainline Tracks	0.87344
Proportion of Trackage with Sidings	0.12799
Carloads Per-Year Supported	80,785

INFRASTRUCTURE IMPROVEMENT	COST
Install (3) 10,000’ Sidings	2,782,608
Upgrade Signals to CTC	28,114,350
TOTAL	30,896,958

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	170,487
Percentage of Original	311.04%
In Ton-Miles (100% ERR)	380,281,727
Incremental Per-Ton-Mile Capacity Cost	0.00406

20196.3138

62818.0912

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	44.50
Siding Size	0
Percent ABS	0
Percent CTC	0
Route Length	**8.36**
Daily Switch Movements	1.74103
Average Train Length	64.814
Train Speed Ratio (Minimum / Timetable	0.49551
Number of Mainline Tracks	1.42085
Proportion of Trackage with Sidings	0.11132
Carloads Per-Year Supported	268,041

INFRASTRUCTURE IMPROVEMENT	COST
Upgrade Signals to CTC	5,057,800
TOTAL	1,053,323

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	176,578
Percentage of Original	165.88%
In Ton-Miles (100% ERR)	70,857,137
Incremental Per-Ton-Mile Capacity Cost	0.00074

67010.1916

111154.64

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	28.5193
Siding Size	0
Percent ABS	0
Percent CTC	0
Route Length	39.83
Daily Switch Movements	0.27778
Average Train Length	59
Train Speed Ratio (Minimum / Timetable	0.24576
Number of Mainline Tracks	0.87344
Proportion of Trackage with Sidings	0.11132
Carloads Per-Year Supported	97,031

INFRASTRUCTURE IMPROVEMENT	COST
Install (3) 10,000' Sidings	2,782,608
Upgrade Signals to CTC	24,097,150
TOTAL	26,879,758

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	185,548
Percentage of Original	291.23%
In Ton-Miles (100% ERR)	354,737,670
Incremental Per-Ton-Mile Capacity Cost	0.00379

24,258

70644.6636

ROUTE CHARACTERISTICS		
State of Operation		Iowa
Average Timetable Speed	**29.15**	
Siding Size	**0**	
Percent ABS	**0**	
Percent CTC	**0**	
Route Length	**30.8**	
Daily Switch Movements	**0.91912**	
Average Train Length	**9.182**	
Train Speed Ratio (Minimum / Timetable	**0.31925**	
Number of Mainline Tracks	**1.15585**	
Proportion of Trackage with Sidings	**0.11132**	
Carloads Per-Year Supported		122,551

INFRASTRUCTURE IMPROVEMENT	COST
Install (2) 10,000' Sidings	1,855,072
Upgrade Signals to CTC	18,634,000
TOTAL	20,489,072

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	208,620
Percentage of Original	270.23%
In Ton-Miles (100% ERR)	308,423,471
Incremental Per-Ton-Mile Capacity Cost	0.00332

30637.7793

82792.7223

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	32.48
Siding Size	0
Percent ABS	1
Percent CTC	0
Route Length	32.55
Daily Switch Movements	0.01587
Average Train Length	391.327
Train Speed Ratio (Minimum / Timetable	0.3845
Number of Mainline Tracks	0.87344
Proportion of Trackage with Sidings	0.11132
Carloads Per-Year Supported	111,096

INFRASTRUCTURE IMPROVEMENT	COST
Install (2) 10,000' Sidings	1,855,072
Upgrade Signals to CTC	19,692,750
TOTAL	21,547,822

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	95,028
Percentage of Original	185.54%
In Ton-Miles (100% ERR)	148,471,295
Incremental Per-Ton-Mile Capacity Cost	0.00726

27773.9365

51530.8642

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	58.67
Siding Size	0
Percent ABS	0
Percent CTC	0
Route Length	25.2
Daily Switch Movements	0
Average Train Length	31.403
Train Speed Ratio (Minimum / Timetable	0.55682
Number of Mainline Tracks	2.0331
Proportion of Trackage with Sidings	0.11132
Carloads Per-Year Supported	574,169

INFRASTRUCTURE IMPROVEMENT	COST
Install ABS	15,246,000
TOTAL	15,246,000

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	309,220
Percentage of Original	153.86%
In Ton-Miles (100% ERR)	187,016,390
Incremental Per-Ton-Mile Capacity Cost	0.00408

220847.355

ROUTE CHARACTERISTICS	
State of Operation	Illinois / Wisconsin
Average Timetable Speed	45.62
Siding Size	1.61333
Percent ABS	0.975
Percent CTC	0.025
Route Length	111.93
Daily Switch Movements	2.90952
Average Train Length	30.349
Train Speed Ratio (Minimum / Timetable	0.03111
Number of Mainline Tracks	1.74064
Proportion of Trackage with Sidings	0.09907
Carloads Per-Year Supported	663,040

INFRASTRUCTURE IMPROVEMENT	COST
Complete Double Main	18,016,846
TOTAL	18,016,846

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	139,169
Percentage of Original	120.99%
In Ton-Miles (100% ERR)	373,851,625
Incremental Per-Ton-Mile Capacity Cost	0.00241

165760.01

200552.18

802208.73

ROUTE CHARACTERISTICS	
State of Operation	Iowa / South Dakota
Average Timetable Speed	33.46
Siding Size	0.21
Percent ABS	0
Percent CTC	0
Route Length	112.08
Daily Switch Movements	0.0625
Average Train Length	44.189
Train Speed Ratio (Minimum / Timetable	0.44321
Number of Mainline Tracks	1.0127
Proportion of Trackage with Sidings	0.09907
Carloads Per-Year Supported	116,787

INFRASTRUCTURE IMPROVEMENT	COST
Install CTC over route	67,808,400
TOTAL	67,808,400

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	277,048
Percentage of Original	337.22%
In Ton-Miles (100% ERR)	745,236,291
Incremental Per-Ton-Mile Capacity Cost	0.00455

69261.938

ROUTE CHARACTERISTICS	
State of Operation	Iowa / Nebraska
Average Timetable Speed	43.6
Siding Size	0.21
Percent ABS	0
Percent CTC	1
Route Length	18.07
Daily Switch Movements	0
Average Train Length	44.05
Train Speed Ratio (Minimum / Timetable	1.0000
Number of Mainline Tracks	1.22875
Proportion of Trackage with Sidings	0.09907
Carloads Per-Year Supported	406,755

INFRASTRUCTURE IMPROVEMENT	COST
Complete Double Track	8,649,333
TOTAL	8,649,333

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	109,972
Percentage of Original	127.04%
In Ton-Miles (100% ERR)	47,692,730
Incremental Per-Ton-Mile Capacity Cost	0.00907

ROUTEID	236
AARRR	76
TIMETBLS	43.6
SPEEDRAT	$0
TRAINLEN	$44
MAINS	1.22875
SIDINGS	0.09907
SIDSIZ	0.21
ABS	0
CTC	1
SWITCH	0
ROUTLEN	18.07
	10.6884
129181.68	11.3514
	101688.63

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	64.03
Siding Size	0
Percent ABS	0.94118
Percent CTC	0.05882
Route Length	80.82
Daily Switch Movements	0
Average Train Length	10.237
Train Speed Ratio (Minimum / Timetable	0.00347
Number of Mainline Tracks	1.54407
Proportion of Trackage with Sidings	0.09907
Carloads Per-Year Supported	683,247

INFRASTRUCTURE IMPROVEMENT	COST
Complete Double Track	22,868,953
TOTAL	22,868,953

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	253,507
Percentage of Original	137.10%
In Ton-Miles (100% ERR)	491,722,154
Incremental Per-Ton-Mile Capacity Cost	0.00233

234188.58

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	17.046
Siding Size	0.000
Percent ABS	0.667
Percent CTC	0.333
Route Length	10.160
Daily Switch Movements	0.000
Average Train Length	63.955
Train Speed Ratio (Minimum / Timetable	0.267
Number of Mainline Tracks	1.632
Proportion of Trackage with Sidings	0.099
Carloads Per-Year Supported	188,073

INFRASTRUCTURE IMPROVEMENT	COST
Add (1) 10,000' Siding	$927,536
Complete CTC installation	$875,729
TOTAL	$1,803,265

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	115,713
Percentage of Original	161.53%
In Ton-Miles (100% ERR)	28,215,541
Incremental Per-Ton-Mile Capacity Cost	$0.00320

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	64.028
Siding Size	0.000
Percent ABS	0.941
Percent CTC	0.059
Route Length	80.820
Daily Switch Movements	0.000
Average Train Length	10.237
Train Speed Ratio (Minimum / Timetable	0.003
Number of Mainline Tracks	1.544
Proportion of Trackage with Sidings	0.099
Carloads Per-Year Supported	683,247

INFRASTRUCTURE IMPROVEMENT	COST
Complete Double Track	22,868,953
TOTAL	$22,868,953

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	253,507
Percentage of Original	137.10%
In Ton-Miles (100% ERR)	491,722,154
Incremental Per-Ton-Mile Capacity Cost	$0.00233

ROUTE CHARACTERISTICS	
State of Operation	Iowa / Nebraska
Average Timetable Speed	43.600
Siding Size	0.210
Percent ABS	0.000
Percent CTC	1.000
Route Length	18.070
Daily Switch Movements	0.000
Average Train Length	44.053
Train Speed Ratio (Minimum / Timetable	1.000
Number of Mainline Tracks	1.229
Proportion of Trackage with Sidings	0.099
Carloads Per-Year Supported	406,755

INFRASTRUCTURE IMPROVEMENT	COST
Complete Double Track	$8,649,333
TOTAL	$8,649,333

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	109,972
Percentage of Original	127.04%
In Ton-Miles (100% ERR)	47,692,730
Incremental Per-Ton-Mile Capacity Cost	$0.00907

ROUTE CHARACTERISTICS	
State of Operation	wa / South Dakota
Average Timetable Speed	33.464
Siding Size	0.210
Percent ABS	0.000
Percent CTC	0.000
Route Length	112.080
Daily Switch Movements	0.063
Average Train Length	44.189
Train Speed Ratio (Minimum / Timetable	0.443
Number of Mainline Tracks	1.013
Proportion of Trackage with Sidings	0.099
Carloads Per-Year Supported	116,787

INFRASTRUCTURE IMPROVEMENT	COST
Install CTC over route	$67,808,400
TOTAL	$67,808,400

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	277,048
Percentage of Original	337.22%
In Ton-Miles (100% ERR)	745,236,291
Incremental Per-Ton-Mile Capacity Cost	$0.00455

ROUTE CHARACTERISTICS	
State of Operation	Illinois / Wisconsin
Average Timetable Speed	45.620
Siding Size	1.613
Percent ABS	0.975
Percent CTC	0.025
Route Length	111.930
Daily Switch Movements	2.910
Average Train Length	30.349
Train Speed Ratio (Minimum / Timetable	0.031
Number of Mainline Tracks	1.741
Proportion of Trackage with Sidings	0.099
Carloads Per-Year Supported	663,040

INFRASTRUCTURE IMPROVEMENT	COST
Complete Double Main	$18,016,846
TOTAL	$18,016,846

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	139,169
Percentage of Original	120.99%
In Ton-Miles (100% ERR)	373,851,625
Incremental Per-Ton-Mile Capacity Cost	$0.00241

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	58.667
Siding Size	0.000
Percent ABS	0.000
Percent CTC	0.000
Route Length	25.200
Daily Switch Movements	0.000
Average Train Length	31.403
Train Speed Ratio (Minimum / Timetable	0.557
Number of Mainline Tracks	2.033
Proportion of Trackage with Sidings	0.111
Carloads Per-Year Supported	574,169

INFRASTRUCTURE IMPROVEMENT	COST
Install ABS	$15,246,000
TOTAL	$15,246,000

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	309,220
Percentage of Original	153.86%
In Ton-Miles (100% ERR)	187,016,390
Incremental Per-Ton-Mile Capacity Cost	0.00408

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	32.482
Siding Size	0.000
Percent ABS	1.000
Percent CTC	0.000
Route Length	32.550
Daily Switch Movements	0.016
Average Train Length	391.327
Train Speed Ratio (Minimum / Timetable	0.385
Number of Mainline Tracks	0.873
Proportion of Trackage with Sidings	0.111
Carloads Per-Year Supported	111,096

INFRASTRUCTURE IMPROVEMENT	COST
Install (2) 10,000' Sidings	$1,855,072
Upgrade Signals to CTC	$19,692,750
TOTAL	$21,547,822

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	95,028
Percentage of Original	185.54%
In Ton-Miles (100% ERR)	148,471,295
Incremental Per-Ton-Mile Capacity Cost	$0.00726

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	29.154
Siding Size	0.000
Percent ABS	0.000
Percent CTC	0.000
Route Length	30.800
Daily Switch Movements	0.919
Average Train Length	9.182
Train Speed Ratio (Minimum / Timetable	0.319
Number of Mainline Tracks	1.156
Proportion of Trackage with Sidings	0.111
Carloads Per-Year Supported	122,551

INFRASTRUCTURE IMPROVEMENT	COST
Install (2) 10,000' Sidings	$1,855,072
Upgrade Signals to CTC	$18,634,000
TOTAL	$20,489,072

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	208,620
Percentage of Original	270.23%
In Ton-Miles (100% ERR)	308,423,471
Incremental Per-Ton-Mile Capacity Cost	$0.00332

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	28.519
Siding Size	0.000
Percent ABS	0.000
Percent CTC	0.000
Route Length	39.830
Daily Switch Movements	0.278
Average Train Length	59.314
Train Speed Ratio (Minimum / Timetable	0.246
Number of Mainline Tracks	0.873
Proportion of Trackage with Sidings	0.111
Carloads Per-Year Supported	97,031

INFRASTRUCTURE IMPROVEMENT	COST
Install (3) 10,000' Sidings	$2,782,608
Upgrade Signals to CTC	$24,097,150
TOTAL	$26,879,758

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	185,548
Percentage of Original	291.23%
In Ton-Miles (100% ERR)	354,737,670
Incremental Per-Ton-Mile Capacity Cost	$0.00379

ROUTE CHARACTERISTICS	
State of Operation	Iowa
Average Timetable Speed	44.500
Siding Size	0.000
Percent ABS	0.000
Percent CTC	0.000
Route Length	8.360
Daily Switch Movements	1.741
Average Train Length	64.814
Train Speed Ratio (Minimum / Timetable	0.496
Number of Mainline Tracks	1.421
Proportion of Trackage with Sidings	0.111
Carloads Per-Year Supported	268,041

INFRASTRUCTURE IMPROVEMENT	COST
Upgrade Signals to CTC	$5,057,800
TOTAL	$1,053,323

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	176,578
Percentage of Original	165.88%
In Ton-Miles (100% ERR)	70,857,137
Incremental Per-Ton-Mile Capacity Cost	$0.00074

ROUTE CHARACTERISTICS	
State of Operation	Illinois
Average Timetable Speed	26.657
Siding Size	0.390
Percent ABS	0.000
Percent CTC	0.000
Route Length	46.470
Daily Switch Movements	0.972
Average Train Length	17.867
Train Speed Ratio (Minimum / Timetable	0.346
Number of Mainline Tracks	0.873
Proportion of Trackage with Sidings	0.128
Carloads Per-Year Supported	80,785

INFRASTRUCTURE IMPROVEMENT	COST
Install (3) 10,000' Sidings	$2,782,608
Upgrade Signals to CTC	$28,114,350
TOTAL	$30,896,958

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	170,487
Percentage of Original	311.04%
In Ton-Miles (100% ERR)	380,281,727
Incremental Per-Ton-Mile Capacity Cost	$0.00406

ROUTE CHARACTERISTICS	
State of Operation	Missouri
Average Timetable Speed	54.348
Siding Size	0.410
Percent ABS	0.000
Percent CTC	1.000
Route Length	58.472
Daily Switch Movements	2.118
Average Train Length	23.092
Train Speed Ratio (Minimum / Timetable	0.630
Number of Mainline Tracks	1.202
Proportion of Trackage with Sidings	0.124
Carloads Per-Year Supported	524,729

INFRASTRUCTURE IMPROVEMENT	COST
Construct 2nd Main Track to Heavy-Haul Standards	$53,099,008
Install (2) 10,000’ Sidings	$1,855,072
TOTAL	$54,954,080

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	397,928
Percentage of Original	175.83%
In Ton-Miles (100% ERR)	1,116,847,116
Incremental Per-Ton-Mile Capacity Cost	$0.00246

ROUTE CHARACTERISTICS	
State of Operation	Illinois / Iowa
Average Timetable Speed	16.282
Siding Size	2.920
Percent ABS	0.000
Percent CTC	0.800
Route Length	28.880
Daily Switch Movements	2.118
Average Train Length	48.119
Train Speed Ratio (Minimum / Timetable	0.256
Number of Mainline Tracks	0.381
Proportion of Trackage with Sidings	0.077
Carloads Per-Year Supported	158,512

INFRASTRUCTURE IMPROVEMENT	COST
Rebuild Track to Medium Density Standards	$17,923,650
Install (2) 10,000’ Sidings	$1,855,072
Upgrade Remaining Track Signals to CTC	$3,978,480
TOTAL	$21,902,130

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	218,514
Percentage of Original	237.85%
In Ton-Miles (100% ERR)	302,912,747
Incremental Per-Ton-Mile Capacity Cost	$0.00362

ROUTE CHARACTERISTICS	
State of Operation	Illinois / Iowa
Average Timetable Speed	19.024
Siding Size	0.600
Percent ABS	0.000
Percent CTC	0.000
Route Length	91.430
Daily Switch Movements	2.201
Average Train Length	140.611
Train Speed Ratio (Minimum / Timetable	0.216
Number of Mainline Tracks	0.883
Proportion of Trackage with Sidings	0.077
Carloads Per-Year Supported	57,512

INFRASTRUCTURE IMPROVEMENT	COST
Rebuild Track to Medium Density Standards	$56,743,744
Install (4) 10,000’ Sidings	$3,710,144
Upgrade Remaining Track Signals to CTC	$55,315,150
TOTAL	$112,058,894

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	236,902
Percentage of Original	511.92%
In Ton-Miles (100% ERR)	1,039,679,096
Incremental Per-Ton-Mile Capacity Cost	$0.00539

ROUTE CHARACTERISTICS	
State of Operation	Missouri
Average Timetable Speed	40.345
Siding Size	0.000
Percent ABS	0.000
Percent CTC	1.000
Route Length	79.079
Daily Switch Movements	0.263
Average Train Length	143.593
Train Speed Ratio (Minimum / Timetable	0.529
Number of Mainline Tracks	0.958
Proportion of Trackage with Sidings	
Carloads Per-Year Supported	312,602

INFRASTRUCTURE IMPROVEMENT	COST
Construct 2nd Main Track to Heavy-Haul Standards	$71,812,431
Install (3) 10,000' Sidings	$2,782,608
TOTAL	$74,595,039

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	323,596
Percentage of Original	203.52%
In Ton-Miles (100% ERR)	1,228,304,146
Incremental Per-Ton-Mile Capacity Cost	$0.00304

Exampl Numb	1	2	3	4	5
State of Operation	Iowa	Iowa	Iowa / Nebraska	Iowa / South Dakota	Illinois / Wisconsin
Carloads Per-	188072.519	683,247	406,755	116,787	663040.0447
INFRASTRUC	COST	COST	COST	COST	COST
TOTAL	1803265	22,868,953	8,649,333	67,808,400	18016846.03
INCREMENTAL CAPACITY IMPROVEMENT					
In Carloads Pe	115713.3402	253,507	10997216.93%	277,048	139168.6861
Percentage of	161.53%	137.10%	1	337.22%	1.209894843
In Ton-Miles (	28215540.87	491,722,154	#############	745,236,291	373851624.9
Incremental P	0.003195517	0.00233	0.009067768	0.00455	0.002409625

Example Number	State of Operation	Carloads Per-Year Supported	Infrastructure Improvement Cost	Inremental Capacity Carloads Per-Year	Percentage of Original
1	IA	188073	$1,803,265	115,713	161.53%
2	IA	683247	$22,868,953	253,507	137.10%
3	IA, NE	406755	$8,649,333	109,972	127.04%
4	IA, SD	116787	$67,808,400	277,048	337.22%
5	IL, WI	663040	$18,016,846	139,169	120.99%
6	IA	574169	$15,246,000	309,220	153.86%
7	IA	111096	$21,547,822	95,028	185.54%
8	IA	122551	$20,489,072	208,620	270.23%
9	IA	97031	$26,879,758	185,548	291.23%
10	IA	268041	$1,053,323	176,578	165.88%
11	IL	80785	$30,896,958	170,487	311.04%
12	IL, IA	158512	$21,902,130	218,514	237.85%
13	IL, IA	57512	$112,058,894	236,902	511.92%
14	MO	524729	$54,954,080	397,928	175.83%
15	MO	312602	$74,595,039	323,596	203.52%
	AVERAGE	290995	$33,251,325	214,522	226.05%

6	7	8	9	10	11	12
Iowa	Iowa	Iowa	Iowa	Iowa	Illinois	Illinois / Iowa
574169.1966	111,096	122551.12	97030.873	268040.77	80785.255	158512.47
COST	COST	COST	COST	COST	COST	COST
15246000	21,547,822	20489072	26879758	1053323.2	30896958	21902130
309220.2215	95,028	208619.77	185547.78	176577.79	170487.11	218513.93
1.538552439	185.54%	2.7023082	2.9122551	1.6587722	3.1103741	2.3785283
187016390	148,471,295	308423471	354737670	70857137	380281727	302912747
0.004076113	0.00726	0.0033216	0.0037887	0.0007433	0.0040624	0.0036153

In Ton-Miles (100% ERR)	Incremental Per-Ton-Mile Capacity Cost
28,215,541	$0.00320
491,722,154	$0.00233
47,692,730	$0.00907
745,236,291	$0.00455
373,851,625	$0.00241
187,016,390	$0.00408
148,471,295	$0.00726
308,423,471	$0.00332
354,737,670	$0.00379
70,857,137	$0.00074
380,281,727	$0.00406
302,912,747	$0.00362
1,039,679,096	$0.00539
1,116,847,116	$0.00246
1,228,304,146	$0.00304
454,949,942	$0.00395

13	14	15
Illinois / Iowa	Missouri	Missouri
57511.566	524729.1	312602.32
COST	COST	COST
112058894	54954080	74595039
236902.34	397928.04	323596.27
5.1192121	1.7583495	2.0351691
1.04E+09	1.117E+09	1.228E+09
0.0053891	0.0024602	0.0030365

ROUTE CHARACTERISTICS	
State of Operation	Missouri
Average Timetable Speed	**40.35**
Siding Size	**0**
Percent ABS	**0**
Percent CTC	**1**
Route Length	**79.079**
Daily Switch Movements	**0.26344**
Average Train Length	**143.593**
Train Speed Ratio (Minimum / Timetable	**0.52895**
Number of Mainline Tracks	**0.95782**
Proportion of Trackage with Sidings	
Carloads Per-Year Supported	312,602

INFRASTRUCTURE IMPROVEMENT	COST
Construct 2nd Main Track to Heavy-Haul Standards	71,812,431
Install (3) 10,000' Sidings	2,782,608
TOTAL	74,595,039

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	323,596
Percentage of Original	203.52%
In Ton-Miles (100% ERR)	1,228,304,146
Incremental Per-Ton-Mile Capacity Cost	0.00304

ROUTE CHARACTERISTICS	
State of Operation	Missouri
Average Timetable Speed	40.3454
Siding Size	0
Percent ABS	0
Percent CTC	1
Route Length	79.079
Daily Switch Movements	0.26344
Average Train Length	143.593
Train Speed Ratio (Minimum / Timetable	0.52895
Number of Mainline Tracks	0.95782
Proportion of Trackage with Sidings	
Carloads Per-Year Supported	312602.3243

INFRASTRUCTURE IMPROVEMENT	COST
Construct 2nd Main Track to Heavy-Haul Standards	71812430.69
Install (3) 10,000' Sidings	2782608
TOTAL	74595038.69

INCREMENTAL CAPACITY IMPROVEMENT	
In Carloads Per-Year	323596.2735
Percentage of Original	2.035169122
In Ton-Miles (100% ERR)	1228304146
Incremental Per-Ton-Mile Capacity Cost	0.003036505

78150.581

159049.65

ROUTE CHARACTERISTICS			
State of Operation	Illinois / Iowa		
Average Timetable Speed	19.02		
Siding Size	0.6		
Percent ABS	0		
Percent CTC	0		
Route Length	91.43		
Daily Switch Movements	2.20068		
Average Train Length	140.611		
Train Speed Ratio (Minimum / Timetable	0.21621		
Number of Mainline Tracks	0.88327		
Proportion of Trackage with Sidings	0.07711		
Carloads Per-Year Supported	57,512		
INFRASTRUCTURE IMPROVEMENT	COST		
Rebuild Track to Medium Density Standards	56,743,744		
Install (4) 10,000’ Sidings	3,710,144	14377.8916	
Upgrade Remaining Track Signals to CTC	55,315,150	73603.4772	
TOTAL	112,058,894		
INCREMENTAL CAPACITY IMPROVEMENT			
In Carloads Per-Year	236,902		
Percentage of Original	511.92%		
In Ton-Miles (100% ERR)	1,039,679,096		
Incremental Per-Ton-Mile Capacity Cost	0.00539		0
			0

14377.8916

73603.4772

ROUTEID	228	230	236	237	277	672
AARRR	76	76	76	76	76	131
TIMETBLS	17.05	64.03	43.60	33.46	45.62	58.67
SPEEDRAT	0.26667	0.00347	1	0.44321	0.03111	0.55682
TRAINLEN	63.955	10.237	44.053	44.189	30.349	31.403
MAINS	1.63185	1.54407	1.22875	1.0127	1.74064	2.0331
SIDINGS	0.09907	0.09907	0.09907	0.09907	0.09907	0.11132
SIDSIZ	0	0	0.21	0	1.61333	0
ABS	0.66667	0.94118	0	0	0.975	0
CTC	0.33333	0.05882	1	0	0.025	0
SWITCH	0	0	0	0.0625	2.90952	0
ROUTLEN	10.16	80.82	18.07	112.08	111.93	25.2
ALTCARM	10.431	12.1762	10.6884	10.777	11.5975	12.43
PVAL	10.7583	12.0484	11.52	10.2819	12.0183	11.8744
CARLOADS	47,019	170,826	101,688	29,199	165,761	143,544

	G	B	B	G	B	G
ROUTEID	**TIMETBLS**	**SPEEDRAT**	**TRAINLEN**	**MAINS**	**SIDINGS**	**SIDSIZ**
1	17	0.26667	64	1.63	0.0991	
2	64	0.00347	10	1.54	0.0991	
3	44	1.00000	44	1.23	0.0991	0.210
4	33	0.44321	44	1.01	0.0991	
5	46	0.03111	30	1.74	0.0991	1.613
6	59	0.55682	31	2.03	0.1113	
7	32	0.38450	391	0.87	0.1113	
8	29	0.31925	9	1.16	0.1113	
9	29	0.24576	59	1.05	0.1113	
10	45	0.49551	65	1.42	0.1113	
11	27	0.34560	18	0.92	0.1280	0.390
12	16	0.25597	48	0.38	0.0771	2.920
13	19	0.21621	141	0.88	0.0771	0.600
14	54	0.62957	23	1.20	0.1241	0.410
15	40	0.52895	144	0.96	0.1241	
MEAN	37	0.38151	75	1.20	0.1055	1.024

673	674	675	676	1588	1797	1799
131	131	131	131	555	482	482
32.48	29.15	28.52	44.50	26.66	16.28	19.02
0.3845	0.31925	0.24576	0.49551	0.3456	0.25597	0.21621
391.327	9.182	59.314	64.814	17.867	48.119	140.611
0.87344	1.15585	1.04701	1.42085	0.91868	0.38129	0.88327
0.11132	0.11132	0.11132	0.11132	0.12799	0.07711	0.07711
0	0	0	0	0.39	2.92	0.6
1	0	0	0	0	0	0
0	0	0	0	0	0.8	0
0.01587	0.91912	0.27778	1.74103	0.97222	2.11829	2.20068
32.55	30.8	39.83	8.36	46.47	28.88	91.43
8.888	10.3898	10.0962	11.5859	10.386	11.0381	10.0608
10.2319	10.33	10.0965	11.1126	9.9133	10.5873	9.5735
27,775	30,638	24,258	67,010	20,197	39,628	14,379

G	G	G	G	
ABS	**CTC**	**SWITCH**	**ROUTLEN**	**CARLOADS**
0.6667	0.3333	0.00	10	47,019
0.9412	0.0588	0.00	81	170,826
0.0000	1.0000	0.00	18	101,688
0.0000	0.0000	0.06	112	29,199
0.9750	0.0250	2.91	112	165,761
0.0000	0.0000	0.00	25	143,544
1.0000	0.0000	0.02	33	27,775
0.0000	0.0000	0.92	31	30,638
0.0000	0.0000	0.28	40	24,258
0.0000	0.0000	1.74	8	67,010
0.0000	0.0000	0.97	46	20,197
0.0000	0.8000	2.12	29	39,628
0.0000	0.0000	2.20	91	14,379
0.0000	1.0000	2.78	58	161,393
0.0000	1.0000	0.26	79	78,151
0.2389	0.2811	0.95	52	54,555

2189	2191	MEAN	ROUTEID
802	802	MEAN	**AARRR**
54.35	40.35	36.92	**TIMETBLS**
0.62957	0.52895	0.38	**SPEEDRAT**
23.092	143.593	74.81	**TRAINLEN**
1.2021	0.95782	1.20	**MAINS**
0.12409	0.12409	0.11	**SIDINGS**
0.41	0	0.41	**SIDSIZ**
0	0	0.24	**ABS**
1	1	0.28	**CTC**
2.7844	0.26344	0.95	**SWITCH**
58.472	79.079	51.61	**ROUTLEN**
12.6332	11.1112	10.95	
11.9916	11.2664	10.91	
161,393	78,151	54,555	

INTERCEP	8.289905		8.289905
TIMETBLS	0.033229	40.35	1.3406373
CTCSPEED	-0.016995	40.3454	-0.68567007
SPEEDRAT	0.178289	0.52895	0.09430597
TRAINLEN	-0.000906	143.593	-0.13009526
MAINS	0.7272	0.95782	0.6965267
CTCMAIN	-0.416919	0.95782	-0.39933336
SIDINGS	0.948858	0.12409	0.11774379
SIDSIZ	0.095958	0	0
ABS	0.430842	0	0
CTC	1.854777	1	1.854777
SWITCH	0.113847	0.26344	0.02999185
SWITCH2	-0.005166	0.06940063	-0.00035852
ROUTLEN	-0.000876	79.079	-0.0692732
ROUTLEN2	3.462E-06	6253.48824	0.02164958
CD076	0.058096	0	0
CD190	-0.292081	0	0
CD712	-0.12475	0	0
CD400	-0.055716	0	0
CD555	-0.207366	0	0
CD482	-0.207169	0	0
CD721	0.035194	0	0
CD802	0.105586	1	0.105586
			11.2663928
			78150.5811
			868.33979

ROUTEID	**2191**
AARRR	802
TIMETBLS	40.35
SPEEDRAT	0.52895
TRAINLEN	143.593
MAINS	0.95782
SIDINGS	0.12409
SIDSIZ	0
ABS	0
CTC	1
SWITCH	0.26344
ROUTLEN	79.079
	10.0608
	9.5735
	14,379
	78150.6
	159050

XMILS SIDNG	9.81291311
FROM SIDNG	1.89393939
NUM SIDNG	3
	15.4947313
NEW VAR	0.1959399

INTERCEP	8.289905		8.289905
TIMETBLS	0.033229	60.00	1.99374
CTCSPEED	-0.016995	60	-1.0197
SPEEDRAT	0.178289	0.52895	0.09430597
TRAINLEN	-0.000906	143.593	-0.13009526
MAINS	0.7272	2	1.4544
CTCMAIN	-0.416919	2	-0.833838
SIDINGS	0.948858	0.1959	0.18588128
SIDSIZ	0.095958	0	0
ABS	0.430842	0	0
CTC	1.854777	1	1.854777
SWITCH	0.113847	0.26344	0.02999185
SWITCH2	-0.005166	0.06940063	-0.00035852
ROUTLEN	-0.000876	79.079	-0.0692732
ROUTLEN2	3.462E-06	6253.48824	0.02164958
CD076	0.058096	0	0
CD190	-0.292081	0	0
CD712	-0.12475	0	0
CD400	-0.055716	0	0
CD555	-0.207366	0	0
CD482	-0.207169	0	0
CD721	0.035194	0	0
CD802	0.105586	1	0.105586
			11.9769717
			159049.649
			1767.21833

INTERCEP	8.289905		8.289905
TIMETBLS	0.033229	69	2.292801
CTCSPEED	-0.016995	69	-1.172655
SPEEDRAT	0.178289	1	0.178289
TRAINLEN	-0.000906	65	-0.05889
MAINS	0.7272	1.2	0.87264
CTCMAIN	-0.416919	1.2	-0.5003028
SIDINGS	0.948858	0.2	0.1897716
SIDSIZ	0.095958	5	0.47979
ABS	0.430842	0	0
CTC	1.854777	1	1.854777
SWITCH	0.113847	0	0
SWITCH2	-0.005166	0	0
ROUTLEN	-0.000876	100	-0.0876
ROUTLEN2	3.462E-06	10000	0.03462
CD076	0.058096	0	0
CD190	-0.292081	0	0
CD712	-0.12475	0	0
CD400	-0.055716	0	0
CD555	-0.207366	0	0
CD482	-0.207169	0	0
CD721	0.035194	0	0
CD802	0.105586	0	0
			12.3731458
			236368.144
			2626.31271
			40.4048109

INTERCEP	8.289905		8.289905	1.1065
TIMETBLS	0.033229	38	1.262702	
CTCSPEED	-0.016995	14.858	-0.25251171	
SPEEDRAT	0.178289	0.4848	0.08643451	
TRAINLEN	-0.000906	79	-0.071574	
MAINS	0.7272	1.158	0.8420976	
CTCMAIN	-0.416919	0.452778	-0.18877175	
SIDINGS	0.948858	0.1079	0.10238178	
SIDSIZ	0.095958	0.3208	0.03078333	
ABS	0.430842	0.161	0.06936556	
CTC	1.854777	0.391	0.72521781	
SWITCH	0.113847	1.97	0.22427859	
SWITCH2	-0.005166	3.8809	-0.02004873	
ROUTLEN	-0.000876	41	-0.035916	
ROUTLEN2	3.462E-06	1681	0.00581962	
CD076	0.058096	0	0	
CD190	-0.292081	0	0	
CD712	-0.12475	0	0	
CD400	-0.055716	0	0	
CD555	-0.207366	0	0	
CD482	-0.207169	0	0	
CD721	0.035194	0	0	
CD802	0.105586	0	0	
			11.0701636	
			64226.0135	
			713.622372	
			9.03319459	

INTERCEP	8.289905		8.289905
TIMETBLS	0.033229	20	0.66458
CTCSPEED	-0.016995	0	0
SPEEDRAT	0.178289	1	0.178289
TRAINLEN	-0.000906	40	-0.03624
MAINS	0.7272	1	0.7272
CTCMAIN	-0.416919	0	0
SIDINGS	0.948858	0	0
SIDSIZ	0.095958	0	0
ABS	0.430842	0	0
CTC	1.854777	0	0
SWITCH	0.113847	0	0
SWITCH2	-0.005166	0	0
ROUTLEN	-0.000876	100	-0.0876
ROUTLEN2	3.462E-06	10000	0.03462
CD076	0.058096	0	0
CD190	-0.292081	0	0
CD712	-0.12475	0	0
CD400	-0.055716	0	0
CD555	-0.207366	0	0
CD482	-0.207169	0	0
CD721	0.035194	0	0
CD802	0.105586	0	0

9.770754
17513.9678

194.599642

4.86499105

Variable	Estimate	Standard Error	"t" value for Parameter=0	Prob
INTERCEP	8.289905	0.27791347	29.829	0.0001
TIMETBLS	0.033229	0.00243702	13.635	0.0001
CTCSPEED	-0.016995	0.00364959	-4.657	0.0001
SPEEDRAT	0.178289	0.09967003	1.789	0.0739
TRAINLEN	-0.000906	0.00006655	-13.614	0.0001
MAINS	0.7272	0.0900223	8.078	0.0001
CTCMAIN	-0.416919	0.13127623	-3.176	0.0015
SIDINGS	0.948858	2.3944918	0.396	0.692
SIDSIZ	0.095958	0.02487152	3.858	0.0001
ABS	0.430842	0.0663255	6.496	0.0001
CTC	1.854777	0.17713154	10.471	0.0001
SWITCH	0.113847	0.0194415	5.856	0.0001
SWITCH2	-0.005166	0.00168581	-3.064	0.0022
ROUTLEN	-0.000876	0.00107524	-0.815	0.4155
ROUTLEN2	3.462E-06	0.00000517	0.669	0.5036
CD076	0.058096	0.06597513	0.881	0.3787
CD190	-0.292081	0.1053082	-2.774	0.0056
CD712	-0.12475	0.08754583	-1.425	0.1544
CD400	-0.055716	0.10384953	-0.537	0.5917
CD555	-0.207366	0.11660165	-1.778	0.0756
CD482	-0.207169	0.12728252	-1.628	0.1039
CD721	0.035194	0.08892445	0.396	0.6923
CD802	0.105586	0.09147584	1.154	0.2486

ROUTEID	TRAINS	ALTCARM	PVAL	RAT
2	46.2287	249634.86	78061.98	0.3127
3	11.1763	60352.24	42285.86	0.70065
6	51.5667	278460.04	128457.65	0.46131
7	17.0235	91926.73	54203.69	0.58964
9	27.1429	146571.66	81607.2	0.55677
10	22.6564	122344.52	115428.02	0.94347
11	40.7704	220160.26	113983.98	0.51773
12	22.7869	123049	104888.37	0.85241
13	1.2844	6935.64	.	.
16	37.3639	201764.82	87901.61	0.43566
17	58.7627	317318.52	85101.76	0.26819
18	27.9613	150990.93	90385.24	0.59861
21	15.953	86146	117927.96	1.36893
26	7.1992	38875.83	72194.99	1.85707
28	16.4512	88836.6	28725.41	0.32335
29	13.7463	74229.85	64427.92	0.86795
30	4.8186	26020.53	24150.74	0.92814
34	20.129	108696.5	69895.45	0.64303
36	6.8518	36999.73	29198.6	0.78916
37	11.6589	62958.14	48320.26	0.7675
38	32.8574	177429.92	53257.02	0.30016
39	34.9475	188716.35	151982.39	0.80535
40	20.4	110159.83	41179.14	0.37381
41	51.1392	276151.42	112759.02	0.40832
42	9.4447	51001.56	71443.69	1.40081
48	4.4735	24157.04	40895.98	1.69292
49	10.914	58935.78	100163.83	1.69954
51	76.3662	412377.55	319406.89	0.77455
52	56.3107	304077.58	307766.13	1.01213
54	63.1045	340764.34	291406.23	0.85515
55	47.281	255317.54	259505.24	1.0164
56	43.2494	233546.66	223613.53	0.95747
70	4.595	24813.16	56748.7	2.28704
71	19.4742	105160.82	121302.48	1.1535
72	17.458	94273.11	186755.83	1.98101
73	54.7014	295387.67	317036.44	1.07329
74	22.2448	120121.95	148135.85	1.23321
75	32.2566	174185.77	217019.81	1.24591
76	3.8175	20614.59	.	.
79	7.0753	38206.64	39373.63	1.03054
80	49.7061	268413.1	237154.73	0.88354
81	17.1486	92602.68	111511.18	1.20419
82	6.4261	34701.04	93851.62	2.70458
83	17.6593	95360.15	130783.81	1.37147

85	16.199	87474.51	108237.13	1.23736
86	13.4636	72703.17	122669.44	1.68726
87	18.11	97794.01	129455.24	1.32375
88	12.1891	65821.15	119319.59	1.81279
89	11.0729	59793.51	206091.62	3.44672
90	45.6112	246300.49	183739.92	0.746
92	8.2939	44786.98	80960.08	1.80767
93	6.1727	33332.51	70069.48	2.10214
94	6.2211	33593.89	43421.05	1.29253
96	3.3635	18162.9	39802.67	2.19143
97	12.2748	66283.67	74893.47	1.12989
105	43.6637	235783.97	107771.48	0.45708
106	10.1885	55018.01	46213.56	0.83997
107	32.6999	176579.24	133255.22	0.75465
108	12.1346	65526.75	82480.07	1.2587
109	11.472	61948.56	65969.76	1.0649
116	9.9802	53893.07	45716.84	0.8483
120	7.0902	38287.16	61149.15	1.5971
124	2.3902	12907.28	27435.38	2.1256
125	20.8247	112453.5	113409.69	1.0085
126	17.6282	95192.42	92727.96	0.9741
130	10.1259	54679.81	73603.01	1.3461
131	14.6656	79194.21	101185.24	1.2777
135	22.8548	123416.09	117389.95	0.9512
137	2.8697	15496.51	25990.74	1.6772
138	52.8629	285459.83	187847.35	0.6581
141	14.631	79007.24	55843.59	0.7068
142	22.4996	121497.59	98225.4	0.8085
144	35.7956	193296.05	138125.35	0.7146
148	13.7266	74123.78	68782.28	0.9279
149	23.2502	125551.34	123984.66	0.9875
150	37.087	200270.02	94368.57	0.4712
151	28.1182	151838.52	105936.52	0.6977
152	10.0202	54108.99	40067.87	0.7405
153	7.2236	39007.21	23358.79	0.5988
154	2.8634	15462.25	19958.36	1.2908
155	30.2348	163267.83	95820.01	0.5869
157	10.363	55960.1	76557.1	1.3681
158	60.8044	328343.59	149410.87	0.455
164	4.4619	24094.14	40058.48	1.6626
165	0.225	1215.17	16977.79	13.9716
166	3.0932	16703.4	67489.72	4.0405
167	7.111	38399.22	72617.26	1.8911
169	8.6494	46706.74	67247.62	1.4398
170	7.3418	39645.46	31904.07	0.8047
171	18.7928	101481.29	99138.13	0.9769

172	56.5018	305109.66	167905.48	0.5503
173	8.2284	44433.34	74130	1.6683
175	22.4461	121209.1	143696.48	1.1855
181	8.0662	43557.45	.	.
182	11.3897	61504.13	.	.
183	5.1252	27675.91	21240.58	0.7675
184	10.9239	58989.01	77358.87	1.3114
185	21.9881	118735.64	112041.25	0.9436
188	28.1379	151944.55	63508.82	0.418
189	5.0419	27226.35	54249.37	1.9925
190	29.3127	158288.76	121338.97	0.7666
191	18.7717	101367.18	90242.24	0.8903
194	10.3438	55856.52	97861.39	1.752
198	2.9788	16085.72	52603.87	3.2702
203	6.2954	33994.99	13017.68	0.3829
204	13.517	72991.95	30345.39	0.4157
205	17.2348	93067.86	79253.41	0.8516
206	16.6644	89987.56	74925.87	0.8326
209	8.7675	47344.65	.	.
210	18.6708	100822.29	36310.55	0.3601
214	12.9037	69680.15	36259.13	0.5204
218	21.151	114215.17	106751.03	0.9346
219	29.9762	161871.69	66859.76	0.413
222	5.809	31368.84	32885.77	1.0484
225	5.6265	30382.96	36957.93	1.2164
226	39.1319	211312.12	324754.55	1.5368
228	6.277	33894.75	47018.89	1.3872
230	35.948	194117.46	170819.41	0.87998
232	20.352	109901.86	106448.92	0.96858
236	8.12	43845.35	85086.25	1.9406
237	8.871	47904.56	29198.03	0.6095
239	39.458	213075.36	118816.76	0.55763
241	21.989	118741.83	61885.09	0.52117
242	16.675	90044.64	66510.71	0.73864
243	7.803	42136.12	27011.53	0.64105
244	16.559	89420.13	54347.19	0.60777
245	33.499	180896.33	71078.4	0.39292
246	24.103	130158.53	60198.72	0.4625
249	6.328	34172.8	24284.11	0.71063
250	23.218	125378.54	49005.37	0.39086
251	15.564	84047.19	31782.12	0.37815
252	20.347	109874.09	163141.97	1.48481
253	27.639	149249.76	165342.29	1.10782
254	24.782	133822.97	93628.87	0.69965
255	6.906	37294.36	51478.8	1.38034
257	8.722	47096.28	84096.95	1.78564

258	24.693	133343.53	149969.99	1.12469
259	25.374	137018.58	112601.17	0.82179
260	25.39	137107.87	150455.18	1.09735
261	3.596	19417.75	29650.6	1.52698
262	94.221	508790.87	118375.01	0.23266
263	176.041	950622.94	.	.
264	3.703	19994.14	26814.92	1.34114
266	26.685	144098	95473.9	0.66256
277	20.153	108827.35	165767.85	1.52322
278	28.655	154735.44	103479.23	0.66875
278	26.953	145548.69	126841.57	0.87147
279	9.876	53331.02	91218.9	1.71043
280	15.21	82134.37	52528.36	0.63954
281	2.382	12862.98	55275.85	4.29728
282	2.207	11916.23	80756.07	6.77698
283	1.771	9562.96	62679.46	6.5544
288	16.577	89516.67	100621.53	1.12405
289	34.863	188262.04	271611.33	1.44273
293	8.838	47727.12	86758.45	1.8178
294	4.087	22069.29	29207.59	1.32345
295	4.032	21773.44	38520.99	1.76917
296	34.077	184016.07	90023.86	0.48922
298	77.353	417705.26	311987.99	0.74691
299	30.373	164016.88	53765.05	0.3278
300	57.798	312110.98	168245.75	0.53906
302	24.513	132368.4	92810.12	0.70115
303	31.037	167600.02	104734.9	0.62491
304	13.935	75251.15	64622.83	0.85876
305	18.712	101045.62	57986.88	0.57387
306	12.412	67024.06	53061.1	0.79167
307	19.397	104743.48	.	.
311	54.149	292405.42	190563.41	0.65171
312	52.795	285090.78	.	.
313	11.329	61176.19	56982.4	0.93145
314	67.051	362073.56	372067.51	1.0276
315	57.736	311773.5	275205.66	0.88271
316	12.528	67652.14	.	.
317	10.993	59360.58	44368.64	0.74744
318	2.6728	14432.96	21199.21	1.46881
319	14.2468	76932.83	77892.56	1.01247
324	41.9821	226703.55	171758.96	0.75764
325	18.5902	100386.85	47710.77	0.47527
326	6.8877	37193.45	31720.9	0.85286
327	9.2768	50094.87	109251.04	2.18088
328	7.0226	37922.28	36930.77	0.97385
329	4.7221	25499.41	30725.92	1.20497

330	9.7758	52789.55	134427.06	2.54647
331	11.7707	63562.03	31758.31	0.49964
334	11.1436	60175.29	60046.32	0.99786
336	0.5177	2795.73	11843.35	4.23623
340	6.4222	34679.92	34956.75	1.00798
341	46.2748	249884.01	92376.41	0.36968
342	7.1011	38346.02	71031.71	1.85239
343	4.5308	24466.34	24780.29	1.01283
344	11.2869	60949.28	103584.13	1.69951
346	27.086	146264.21	99563.2	0.68071
347	7.9989	43194.24	86422.35	2.00078
348	12.4063	66993.87	41012.63	0.61218
352	41.1655	222293.64	110203.83	0.49576
353	3.2777	17699.36	49520.32	2.79786
355	40.628	219391.31	103505.59	0.47179
356	10.1647	54889.28	132478.51	2.41356
357	9.2135	49753.07	105680.26	2.1241
358	5.6527	30524.67	46136.93	1.51146
359	16.2137	87553.94	125648.46	1.4351
360	16.5285	89253.76	94499.61	1.05877
361	10.0869	54469.08	80095.48	1.47048
362	12.1357	65532.79	.	.
363	4.7563	25684.07	82450.44	3.21018
364	27.1456	146586.01	79496.02	0.54232
366	22.2722	120270.14	105232.05	0.87496
369	19.5031	105317	149059.71	1.41534
371	20.4488	110423.74	201907.87	1.82848
373	19.0651	102951.3	74968.01	0.72819
374	40.8997	220858.16	.	.
375	10.9981	59389.65	50257.11	0.84623
376	16.9668	91620.67	91198.48	0.99539
377	14.8429	80151.7	99956.85	1.2471
378	64.2034	346698.2	201100.18	0.58004
378	28.089	151680.46	94986.9	0.62623
379	32.5686	175870.6	.	.
381	7.83	42281.92	57031.74	1.34884
382	29.419	158862.42	149249.29	0.93949
383	26.217	141571.88	145533.03	1.02798
385	29.3507	158493.61	103734.88	0.65451
386	5.2228	28203.34	31796.2	1.12739
387	18.7188	101081.3	71178.2	0.70417
389	32.3299	174581.46	149841.83	0.85829
390	9.3678	50585.86	120293.78	2.37801
391	16.9873	91731.22	81499.33	0.88846
394	10.9547	59155.49	63153.71	1.06759
395	10.0459	54247.69	68662.32	1.26572

396	22.5187	121600.77	98321.57	0.80856
397	4.6061	24872.97	29872.11	1.20099
398	37.6318	203211.49	180654.84	0.889
403	8.4806	45795.29	49496.19	1.08081
404	8.3971	45344.21	34112.44	0.7523
407	22.2744	120281.54	92870.81	0.77211
409	1.5925	8599.47	49624.81	5.77069
410	8.0669	43561.53	100259.4	2.30156
411	6.3716	34406.87	54872.87	1.59482
412	22.6283	122192.68	105121.38	0.86029
413	43.5409	235120.86	145664.8	0.61953
415	24.5323	132474.18	93511.1	0.70588
416	10.6235	57366.77	90904.07	1.58461
417	10.9183	58958.73	35193.04	0.59691
418	41.4874	224031.9	.	.
419	17.9641	97006.29	70610.96	0.7279
420	30.7324	165955.12	.	.
421	6.6025	35653.66	91972.03	2.5796
422	10.9081	58903.98	60856.31	1.03314
424	4.5556	24600	51457.42	2.09176
426	11.2177	60575.69	.	.
427	4.552	24580.58	41560.8	1.6908
428	2.0653	11152.53	19141.24	1.71631
429	19.8966	107441.86	85770.16	0.79829
431	9.5093	51350.12	80922.2	1.57589
432	7.5901	40986.39	34879.94	0.85101
436	20.1293	108697.99	165941.93	1.52663
439	4.1861	22604.86	23375.6	1.0341
440	15.61	84293.76	146558.69	1.73867
442	4.8519	26200.48	60626.96	2.31396
443	10.6	57239.77	66884.24	1.16849
444	0.8904	4808.11	31076.08	6.46326
445	89.7346	484567.08	165237.8	0.341
446	4.7108	25438.3	24162.96	0.94987
447	1.739	9390.39	.	.
448	47.6146	257119.07	110681.54	0.43047
449	77.2892	417361.42	171428.2	0.41074
450	29.19	157626.23	98279.01	0.62349
451	25.6727	138632.41	63193.82	0.45584
452	45.8231	247444.55	115995.55	0.46877
454	10.5004	56702.04	34441.05	0.6074
456	63.1849	341198.6	132201.35	0.38746
457	36.8291	198877.26	144551.95	0.72684
459	20.4967	110682.01	68236.57	0.61651
460	11.3777	61439.51	44856.97	0.7301
462	24.4455	132005.61	89598.24	0.67875

463	63.4619	342694.09	176321.65	0.51452
464	2.0261	10941.16	25787.26	2.3569
465	8.8416	47744.86	43684.5	0.91496
470	1.0623	5736.22	27406.12	4.77773
473	5.8135	31393.15	29554.14	0.94142
474	12.5021	67511.5	83973.37	1.24384
475	2.7564	14884.67	30345.74	2.03872
476	4.3834	23670.48	29922.43	1.26412
477	28.6295	154599.52	78713.59	0.50915
480	18.9764	102472.6	74734.21	0.72931
482	1.37	7397.95	25634.21	3.46504
483	3.9338	21242.7	32780.17	1.54313
485	30.9094	166910.73	85431.55	0.51184
486	6.3083	34065.04	80441.06	2.3614
487	2.7477	14837.69	55429.2	3.7357
488	1.7703	9559.66	.	.
489	10.8115	58381.94	25829.5	0.4424
493	5.2697	28456.34	30412.83	1.0688
495	8.932	48232.64	27320.3	0.5664
499	21.7038	117200.44	125495.15	1.0708
500	1.6557	8940.93	61349.91	6.8617
501	2.6402	14256.9	51924.95	3.6421
502	6.5698	35476.89	87741.65	2.4732
505	3.5885	19378.04	20547.98	1.0604
506	6.7725	36571.37	36207.88	0.9901
507	16.2309	87646.85	102919.42	1.1743
508	14.7563	79683.8	139944.25	1.7562
509	2.6773	14457.29	30907.42	2.1378
510	2.238	12085.32	.	.
511	49.036	264794.54	118497.84	0.4475
512	35.9489	194123.97	91167.63	0.4696
514	42.4383	229166.61	93912.22	0.4098
515	23.5524	127183.16	54429.54	0.428
517	15.6215	84356.17	80234.66	0.9511
518	73.2879	395754.77	176829.2	0.4468
519	7.8521	42401.07	32526.58	0.7671
520	13.8715	74905.85	41481.35	0.5538
521	5.6511	30516.12	26773.11	0.8773
523	5.7691	31152.93	84111.29	2.6999
524	8.3623	45156.38	52144.18	1.1547
525	17.5878	94974.03	140193.22	1.4761
526	12.5517	67779.18	126516.14	1.8666
527	8.3786	45244.21	96050.7	2.1229
528	1.7762	9591.41	29811.94	3.1082
530	40.4005	218162.74	123153.46	0.5645
531	31.6071	170678.34	113443.74	0.6647

532	87.0671	470162.55	116685.79	0.2482
533	25.1199	135647.55	33539.08	0.2473
534	35.3988	191153.27	95163.05	0.4978
535	57.3004	309422.14	127157.8	0.411
536	10.1477	54797.5	103020.15	1.88
537	23.5257	127038.71	78507.73	0.618
538	28.338	153025.47	109245.03	0.7139
539	14.7361	79575.06	144232.83	1.8125
541	15.3467	82871.95	199306.38	2.405
542	5.9279	32010.89	25226	0.788
543	4.045	21842.83	29233.13	1.3383
544	3.8233	20645.76	23750.94	1.1504
545	4.6825	25285.41	21756.59	0.8604
546	32.1581	173653.51	144142.59	0.8301
547	7.7883	42056.91	32711.81	0.7778
548	24.8434	134154.34	79721.86	0.5943
551	5.3481	28879.62	30944.27	1.0715
552	13.9061	75092.89	109166.69	1.4538
554	4.5602	24625.19	35164.85	1.428
557	24.9354	134651.3	52655.46	0.3911
558	7.3758	39829.18	70482.46	1.7696
559	4.7345	25566.44	20812.58	0.8141
560	0.0617	332.92	121.48	0.3649
561	0.0673	363.34	8509.37	23.4199
562	1.0944	5909.94	22261.83	3.7668
564	25.1973	136065.69	84488.82	0.6209
565	22.8534	123408.56	85816.62	0.6954
566	19.2423	103908.66	87170.14	0.8389
568	19.1975	103666.75	.	.
569	8.9454	48305.4	73930.06	1.53047
570	6.6741	36040.39	33146.94	0.91972
580	20.8175	112414.47	56352.04	0.50129
582	24.128	130291.22	38025.6	0.29185
584	7.1861	38805.02	39448.93	1.01659
586	2.8651	15471.32	19308.62	1.24803
588	6.2844	33935.86	45225.67	1.33268
589	5.4209	29272.68	24605.08	0.84055
591	28.1681	152107.84	95882.81	0.63036
592	34.0515	183877.93	120745.91	0.65666
595	44.4767	240174.28	153986.71	0.64115
596	35.4657	191514.65	160237.51	0.83669
597	42.8796	231549.8	193102.46	0.83396
602	14.0105	75656.92	60191.49	0.79558
603	16.1637	87284.09	56744.32	0.65011
604	3.4259	18499.9	31208.94	1.68698
609	20.5061	110732.87	158380.06	1.43029

611	3.1391	16951.3	20828.39	1.22872
612	16.173	87333.95	49710.7	0.5692
614	24.1137	130214.23	129025.41	0.99087
615	26.6979	144168.42	122218.45	0.84775
616	22.8498	123388.83	115363.86	0.93496
617	5.1845	27996.29	.	.
620	5.7348	30968.06	46925.3	1.51528
622	11.8548	64015.79	34855.37	0.54448
625	0.9016	4868.51	.	.
626	1.0414	5623.36	27728.58	4.93097
629	23.4188	126461.71	74706.24	0.59074
631	32.4532	175247.05	.	.
640	15.4948	83671.94	.	.
641	19.1682	103508.34	92120.68	0.88998
642	12.7399	68795.48	48908.58	0.71093
643	39.7416	214604.64	129420.23	0.60306
644	8.6257	46578.61	31512.41	0.67654
646	11.195	60453.04	63740.07	1.05437
647	17.6135	95113.02	44494.74	0.46781
655	31.2838	168932.57	87774.27	0.51958
656	11.8614	64051.38	.	.
658	3.399	18354.57	.	.
663	9.0423	48828.53	30090.81	0.61625
666	50.2437	271315.85	114473.82	0.42192
668	0.9227	4982.74	9655.07	1.9377
669	57.2496	309147.63	173845.03	0.56234
670	2.602	14050.97	11596.33	0.8253
671	17.7292	95737.42	72025.99	0.75233
672	46.3341	250204.12	143546.48	0.57372
673	1.3416	7244.6	27774.91	3.83388
674	6.0233	32525.56	30638.51	0.94198
675	4.4911	24251.68	24258.35	1.00027
676	19.9204	107570.01	67008.82	0.62293
677	47.585	256958.91	184909.16	0.71961
678	7.6745	41442.56	30345.28	0.73223
679	39.6169	213931.29	118370.1	0.55331
679	1.9378	10464.03	15887.9	1.51833
680	3.3972	18345.07	39107.23	2.13176
681	3.5284	19053.29	19586.91	1.02801
682	2.8229	15243.88	33026.18	2.16652
683	4.133	22316.28	27733.5	1.2427
684	0.134	724.13	20467.41	28.2648
688	2.232	12051.08	26567.09	2.2045
689	1.103	5955.5	19563.88	3.285
690	3.039	16412.13	17772.45	1.0829
691	0.238	1287.77	17464.35	13.5617

692	4.623	24962.55	27160.44	1.088
693	2.462	13297.02	51217.48	3.8518
694	13.758	74295.77	63775.58	0.8584
695	47.479	256388.62	93402.02	0.3643
697	19.393	104724.32	43704.45	0.4173
700	1.722	9299.35	26535.11	2.8534
701	7.537	40699.98	52346.33	1.2862
704	59.28	320111.6	138394.67	0.4323
705	136.048	734660.25	169848.39	0.2312
706	4.581	24737.57	24777.72	1.0016
707	64.614	348914.13	132238.68	0.379
708	18.372	99211.04	34062.93	0.3433
709	73.839	398728.34	138429.93	0.3472
710	41.47	223936.61	57929.64	0.2587
711	14.972	80848.12	48966.39	0.6057
725	31.642	170866.73	45471.1	0.2661
727	116.912	631323.01	.	.
728	82.917	447749.24	276386.41	0.6173
732	12.139	65549.62	36898.6	0.5629
733	55.227	298226.35	138888.72	0.4657
734	30.736	165975.1	130157.74	0.7842
736	2.421	13071.2	23735.26	1.8158
737	3.448	18618.31	57022.97	3.0627
738	8.127	43884.17	39594.41	0.9022
740	4.542	24526.58	76826.62	3.1324
742	3.912	21125.33	24229.21	1.1469
743	7.65	41310.55	26430.26	0.6398
744	10.526	56839.39	33125.71	0.5828
745	8.326	44961.28	52412.2	1.1657
746	5.037	27199.71	35401.65	1.3015
748	5.042	27229.3	.	.
749	8.478	45779.06	95394.81	2.0838
752	2.83	15282.23	30646.5	2.0054
756	5.712	30845.26	91584.09	2.9691
757	5.266	28434.23	43816.55	1.541
758	1.412	7624.99	43383	5.6896
760	57.052	308079.47	122158.05	0.3965
761	1.471	7945.18	37540.65	4.725
762	25.27	136457.55	38061.91	0.2789
763	22.522	121619.22	127941.65	1.052
764	0.711	3837.9	11679.64	3.0432
765	22.074	119198.77	41754.63	0.3503
766	0.175	947.2	12423.99	13.1165
767	9.385	50679.94	32228.59	0.6359
768	26.94	145475.36	121941.89	0.8382
769	17.685	95497.48	97734.1	1.0234

772	11.467	61921.18	118533.29	1.9143
779	2.522	13618.74	.	.
780	20.802	112332.01	74954.98	0.6673
782	10.487	56632.24	26941.94	0.4757
786	13.487	72827.88	143086.44	1.9647
787	2.212	11946.48	25040.58	2.0961
788	2.1801	11772.64	22297.86	1.894
789	2.4329	13137.67	28597.57	2.1768
792	8.9661	48416.97	42772.73	0.8834
793	25.4236	137287.37	85094.42	0.6198
794	13.5737	73298.15	27723.03	0.3782
795	13.5613	73230.98	45327.61	0.619
803	19.8852	107380.02	197165.32	1.8361
804	3.2863	17745.76	22845.4	1.2874
805	9.5994	51836.9	44746.94	0.8632
806	3.4512	18636.63	33921.44	1.8201
809	7.2194	38984.57	50342.6	1.2913
813	14.2377	76883.66	71247.78	0.9267
814	4.6057	24870.68	35788.1	1.439
815	2.5166	13589.66	.	.
816	4.5325	24475.3	59307.44	2.4232
818	7.7463	41829.79	47988.5	1.1472
819	15.1732	81935.43	53752.87	0.656
820	73.1752	395146.25	97902.05	0.2478
821	43.2764	233692.63	73905.22	0.3162
822	59.0043	318623.1	77516.69	0.2433
823	51.159	276258.74	68304.04	0.2472
824	14.2043	76703.3	85151.78	1.1101
827	3.4774	18777.81	23684.92	1.2613
830	6.2421	33707.45	18415.99	0.5463
831	9.4582	51074.1	51430.03	1.007
832	2.5928	14001.19	14851	1.0607
834	15.9729	86253.78	74625.79	0.8652
835	25.6795	138669.28	140465.97	1.013
836	59.2829	320127.42	96206.06	0.3005
837	6.409	34608.42	47426.69	1.3704
839	11.8311	63888.11	38922.16	0.6092
840	13.1989	71273.87	61200.75	0.8587
843	13.3742	72220.85	49829.76	0.69
845	7.0359	37994.09	34346.36	0.904
847	19.2202	103789.18	163488.8	1.5752
848	18.6685	100810.04	141810.16	1.4067
849	2.8244	15251.86	27547.78	1.8062
850	15.998	86389.16	109069.64	1.2625
851	24.1486	130402.47	127263.77	0.9759
855	21.6659	116995.77	85006.55	0.7266

857	15.0947	81511.38	180803.25	2.2181
859	5.0865	27467.22	20496.94	0.7462
860	10.7297	57940.55	76664.32	1.3232
861	2.0338	10982.36	21594.95	1.9663
862	6.781	36617.6	85196.88	2.3267
863	3.6824	19884.94	29184.18	1.4677
864	1.1743	6341.26	14939.62	2.3559
865	2.0052	10827.93	37209.7	3.4365
866	20.4114	110221.71	85077.88	0.7719
867	24.8312	134088.75	110314.39	0.8227
868	0.0633	341.68	7647	22.3807
870	1.8486	9982.67	21786.99	2.1825
871	19.8116	106982.85	75857.87	0.7091
872	8.3944	45329.77	63448.39	1.3997
873	4.6771	25256.16	25325.32	1.0027
874	5.6094	30290.88	71128.4	2.3482
876	17.41	94014.26	63088.57	0.6711
877	3.3603	18145.41	21184.49	1.1675
881	2.3598	12742.75	14530.82	1.14032
882	0.8465	4571.23	20100.54	4.39718
883	0.8505	4592.91	14917.3	3.2479
886	8.266	44636.45	45724.68	1.02438
888	6.1804	33374.37	13756.51	0.41219
889	39.2088	211727.6	128809.79	0.60838
890	11.1837	60392	66327.06	1.09828
891	15.6528	84525.01	95530.26	1.1302
892	28.5908	154390.3	306282.98	1.98382
893	19.5978	105828.25	47337.9	0.44731
894	11.1354	60131.09	51463.47	0.85585
895	10.2837	55531.86	50769.21	0.91424
896	7.8608	42448.52	32915.3	0.77542
897	8.4046	45384.9	45486.36	1.00224
900	9.4958	51277.08	25109.97	0.48969
901	10.9865	59326.96	52745.91	0.88907
902	39.7244	214511.78	72134.05	0.33627
903	23.6792	127867.54	66149.09	0.51733
904	21.0606	113727.15	210118.89	1.84757
905	12.0238	64928.37	59985.88	0.92388
906	14.101	76145.54	60653.08	0.79654
907	16.3308	88186.56	25557.17	0.28981
908	8.4476	45617.28	19758.78	0.43314
909	5.5675	30064.69	31782.79	1.05715
910	0.6699	3617.23	.	.
911	18.5855	100361.56	75309.59	0.75038
914	4.7254	25517.06	17852.07	0.69961
915	9.7099	52433.59	16513.11	0.31493

916	23.7095	128031.54	166039.69	1.29687
917	21.867	118081.58	.	.
918	5.6828	30687.33	23455.88	0.76435
919	2.3496	12687.76	.	.
920	4.1128	22209.2	12532.08	0.56427
922	5.0103	27055.58	17843.45	0.65951
924	0.7946	4291.05	8088.73	1.88502
925	8.809	47568.69	40770.54	0.85709
926	19.885	107379.22	51140.49	0.47626
927	13.6761	73850.7	.	.
928	22.0473	119055.21	67260.25	0.56495
931	3.9159	21145.97	8996	0.42542
937	23.4722	126750.09	97779.46	0.77144
938	11.7086	63226.6	39645.2	0.62703
939	42.8004	231122.43	185889.01	0.80429
940	2.3662	12777.52	65710.43	5.14266
941	3.4987	18893.1	13348.14	0.70651
943	8.3618	45153.69	21296.76	0.47165
944	5.5398	29915.02	17789.44	0.59467
945	4.7206	25491.22	26874.47	1.05426
946	22.7713	122965.09	104688.68	0.85137
947	8.7638	47324.4	97539.42	2.06108
951	9.6197	51946.21	42018.81	0.80889
952	19.363	104560.38	47723.59	0.45642
953	1.7833	9629.94	14532.49	1.50909
955	2.1711	11723.98	15190.68	1.29569
956	7.8837	42571.95	67291.95	1.58066
957	6.2544	33773.8	63889.52	1.89169
958	2.0047	10825.28	17978.29	1.66077
959	3.6437	19675.88	55204.99	2.80572
962	6.0099	32453.51	35974.65	1.1085
963	5.2736	28477.58	27669.61	0.9716
966	12.6906	68528.99	77967.34	1.1377
967	8.4372	45560.8	78894.74	1.7316
968	0.857	4627.99	4633.86	1.0013
974	3.8865	20986.89	29629.29	1.4118
975	7.4054	39988.91	40372.16	1.0096
981	1.3322	7194	19126.37	2.6587
983	1.6646	8988.71	14225.25	1.5826
985	0.3291	1777.06	100.78	0.0567
986	3.4137	18434	48178.38	2.6136
987	0.691	3731.56	14907.51	3.995
989	4.5785	24723.87	32352.66	1.3086
990	2.8259	15259.77	16204.99	1.0619
994	3.6773	19857.39	.	.
996	5.6766	30653.45	14319.03	0.4671

997	3.4028	18375.31	.	.
999	50.0864	270466.48	.	.
1000	3.0382	16406.06	13436.94	0.819
1005	5.9229	31983.59	23048.71	0.7206
1006	12.6226	68161.78	36670.18	0.538
1007	18.283	98728.2	73812.21	0.7476
1008	9.2117	49743.15	28935.68	0.5817
1009	6.3891	34501.32	29169.2	0.8455
1010	15.8511	85595.78	78567.12	0.9179
1011	4.8067	25956.11	19003.09	0.7321
1012	6.9431	37492.69	31616.81	0.8433
1014	11.1414	60163.75	79293.62	1.318
1015	9.8349	53108.53	70915.55	1.3353
1016	14.0381	75805.48	116508.74	1.5369
1017	20.0305	108164.63	110889.13	1.0252
1018	9.9726	53852.01	66061.02	1.2267
1021	12.3462	66669.44	31905.11	0.4786
1022	11.4427	61790.75	92220.94	1.4925
1023	12.3095	66471.31	117004.79	1.7602
1024	10.6022	57251.67	28698.1	0.5013
1025	15.8326	85495.86	99974.8	1.1694
1026	0.2056	1110.26	818.84	0.7375
1027	10.5296	56859.81	.	.
1028	14.3293	77377.96	108072.1	1.3967
1029	10.6931	57742.63	44227.47	0.7659
1030	10.8379	58524.6	43022.32	0.7351
1031	18.3039	98841.14	93693.26	0.9479
1032	9.561	51629.43	86962.44	1.6844
1033	9.7147	52459.32	98911.86	1.8855
1034	20.1055	108569.56	106284.15	0.9789
1035	14.1741	76540.32	82210.73	1.0741
1036	8.683	46888.31	77358.68	1.6499
1037	8.3609	45148.69	.	.
1038	11.9315	64430.34	87072.53	1.3514
1039	7.2152	38961.89	92801.01	2.3818
1040	5.0529	27285.65	34461.8	1.263
1041	3.8255	20657.57	21069.87	1.02
1042	0.5172	2792.96	32230.32	11.5398
1043	11.5739	62499.11	65719.95	1.0515
1047	10.4228	56282.89	14921.09	0.2651
1049	9.5826	51746.11	18380.43	0.3552
1050	1.9731	10654.95	21829.7	2.0488
1051	0.8889	4800	.	.
1052	3.9038	21080.38	.	.
1053	1.3992	7555.81	23097.56	3.05693
1056	16.3759	88429.82	47354.87	0.53551

1058	24.2103	130735.7	38838.15	0.29707
1059	11.1898	60424.96	61173.93	1.0124
1060	19.9423	107688.61	70527.51	0.65492
1062	31.806	171752.37	89606	0.52172
1063	35.0129	189069.45	79701.76	0.42155
1064	18.2967	98802.29	95692.48	0.96852
1065	14.3485	77481.72	77694.91	1.00275
1066	9.4833	51209.7	80855	1.5789
1067	5.3564	28924.33	26718.79	0.92375
1068	6.3204	34130.12	42283.94	1.2389
1070	20.1557	108840.76	52622.81	0.48348
1071	22.8134	123192.15	74427.38	0.60416
1072	20.3375	109822.39	89093.82	0.81125
1073	13.3348	72007.98	84473.26	1.17311
1077	11.9292	64417.68	53862.34	0.83614
1080	9.4016	50768.63	96075.31	1.89242
1082	14.7265	79522.84	55301.64	0.69542
1084	5.4795	29589.39	44250.72	1.49549
1085	15.6148	84319.74	157570.9	1.86873
1086	2.9294	15818.66	33081.36	2.09129
1089	5.2032	28097.36	71142	2.53198
1090	4.1854	22601.34	40377.83	1.78652
1092	17.0571	92108.57	24856.64	0.26986
1093	20.0071	108038.51	61638.85	0.57053
1094	16.2705	87860.67	112936.93	1.28541
1095	12.2704	66260.01	113292.97	1.70982
1096	19.1523	103422.21	57119.57	0.55229
1097	3.8478	20778.15	38011.42	1.82939
1098	1.9882	10736.13	8800.47	0.81971
1099	11.0258	59539.48	45527.59	0.76466
1100	24.6623	133176.52	.	.
1103	18.056	97502.26	89913.71	0.92217
1104	6.1157	33024.94	27223.29	0.82433
1106	19.751	106655.49	173498.6	1.62672
1108	25.3695	136995.51	151186.15	1.10358
1109	14.1989	76674.08	101908.87	1.32912
1110	11.7409	63401.04	33198.7	0.52363
1111	5.1433	27773.72	44668.74	1.60831
1112	8.0804	43634.1	22000.79	0.50421
1114	14.7095	79431.46	47760.11	0.60127
1115	18.6316	100610.5	95873.99	0.95292
1116	19.4591	105079.39	110582.27	1.05237
1117	9.5767	51714.41	61057.32	1.18066
1118	4.0081	21643.52	87324.14	4.03465
1119	6.4303	34723.65	25914.28	0.7463
1120	1.2955	6995.43	23559.7	3.36787

1122	20.3149	109700.54	89942.41	0.81989
1123	13.157	71047.97	72668.01	1.0228
1124	34.371	185603.44	.	.
1125	16.0655	86753.86	67561.42	0.77877
1126	9.0125	48667.25	86419.13	1.77571
1127	13.9514	75337.42	52208.59	0.693
1128	8.6548	46736.04	88285.85	1.88903
1129	4.9188	26561.36	58061.96	2.18596
1131	9.8737	53318.07	15324.89	0.28742
1132	7.4919	40456.46	29681.15	0.73366
1133	9.9459	53707.88	33233.57	0.61878
1134	21.2636	114823.2	.	.
1135	1.4466	7811.42	39880.03	5.10535
1137	26.0452	140644.04	.	.
1138	5.9607	32187.64	46061.32	1.43103
1140	12.1595	65661.48	41072.09	0.62551
1141	15.0204	81110.07	31918.27	0.39352
1142	8.1217	43857.12	18458.18	0.42087
1143	17.5377	94703.56	66135.07	0.69834
1144	23.7008	127984.25	75188.35	0.58748
1145	31.0549	167696.44	82339.95	0.49101
1146	27.7446	149820.74	105654.72	0.70521
1147	3.998	21588.96	10551.2	0.48873
1148	53.6293	289598.35	.	.
1149	4.9448	26702.12	32293.86	1.20941
1150	9.5259	51439.89	59891.26	1.1643
1152	53.7725	290371.64	226746.04	0.78088
1153	22.7874	123052	97655.37	0.79361
1154	3.6256	19578.5	21871.74	1.11713
1155	4.3065	23255.06	22162.63	0.95302
1157	2.138	11545.21	20733.08	1.79582
1158	2.9916	16154.52	15928.69	0.98602
1159	15.1962	82059.42	57668.14	0.70276
1160	4.6756	25248.01	26654.86	1.05572
1161	10.0705	54380.89	73508.17	1.35173
1162	2.5389	13710.14	21789.37	1.58929
1164	26.3872	142490.66	135711.68	0.95243
1165	6.3039	34041.06	28169.75	0.82752
1167	0.2796	1510.03	14067.48	9.31606
1168	24.3876	131693.16	104869.46	0.79632
1169	27.9135	150733.06	85688.3	0.56848
1170	23.2654	125633.28	112471.29	0.89523
1171	23.7952	128494.18	74263.36	0.57795
1172	41.5759	224509.81	93807.63	0.41783
1173	34.7159	187465.97	120690.54	0.6438
1174	27.4865	148427	105916.43	0.71359

1176	15.932	86032.7	89269.95	1.03763
1177	14.8483	80181.06	65128.6	0.81227
1178	13.8778	74940.31	56939.52	0.7598
1179	3.8618	20853.93	18759.72	0.89958
1180	13.9114	75121.66	81074.79	1.07925
1181	20.6789	111666.29	172590.27	1.54559
1182	8.412	45424.96	39080.8	0.86034
1183	9.0984	49131.15	39174.54	0.79735
1184	17.7012	95586.51	156525.66	1.63753
1185	16.1183	87038.96	165740.82	1.90421
1186	3.8911	21011.96	21764.84	1.03583
1187	15.1449	81782.23	151105.74	1.84766
1188	5.453	29446.38	25707.38	0.87302
1189	11.9767	64674.2	107312.03	1.65927
1190	10.5126	56768.18	44982.64	0.79239
1191	13.2178	71375.97	55096.63	0.77192
1192	12.3499	66689.41	76943.77	1.15376
1193	14.4765	78173.36	143276.74	1.83281
1194	6.4994	35096.57	34633.02	0.98679
1195	1.8637	10063.73	24288.23	2.41344
1196	1.6616	8972.79	17236.61	1.92099
1197	8.1792	44167.79	26877.58	0.60853
1198	15.1037	81560.24	113249.92	1.38854
1200	5.0818	27441.59	60057.3	2.18855
1201	14.428	77910.95	65731.08	0.84367
1202	6.8016	36728.56	64103.62	1.74533
1203	20.7514	112057.82	179678.81	1.60345
1205	23.7091	128028.9	96184.37	0.75127
1206	8.8828	47967.27	71838.29	1.49765
1208	16.0318	86571.46	135942.08	1.57029
1209	25.0895	135483.48	80811.36	0.59647
1210	0.903	4876.06	.	.
1211	6.9425	37489.37	28494.48	0.76007
1212	19.067	102961.65	115100.53	1.1179
1213	12.2911	66371.76	64767.76	0.97583
1214	26.866	145076.44	72571.56	0.50023
1215	16.6104	89695.96	72442.29	0.80764
1216	12.091	65291.66	35415.13	0.54241
1217	18.6281	100591.51	70636.78	0.70221
1218	26.0138	140474.26	75885.12	0.54021
1219	25.5121	137765.24	101900.92	0.73967
1220	3.9131	21130.53	18487.77	0.87493
1221	2.3083	12464.89	20367.29	1.63397
1222	15.8154	85402.9	50245.83	0.58834
1223	5.3865	29086.92	.	.
1225	5.6997	30778.46	19309.18	0.62736

1227	10.6492	57505.7	18049.07	0.31387
1228	0.3613	1951.09	6176.62	3.16572
1230	4.6558	25141.29	11600.23	0.4614
1231	25.9053	139888.56	107484.53	0.76836
1232	10.1419	54766.43	48165.13	0.87946
1233	3.436	18554.19	22850.66	1.23156
1234	3.0844	16655.85	9392.01	0.56389
1237	10.4053	56188.82	28203.64	0.50194
1239	10.9381	59065.95	42093.44	0.71265
1240	26.7438	144416.53	79287.57	0.54902
1241	7.4892	40441.84	22270.32	0.55068
1242	6.2166	33569.41	18250.47	0.54366
1243	6.8011	36725.79	118511.77	3.22694
1244	18.2615	98612.07	114485.81	1.16097
1245	10.452	56441.03	64719.79	1.14668
1246	16.3717	88406.93	144566.11	1.63524
1247	2.3944	12929.95	25983.86	2.00959
1248	19.4288	104915.47	109466.41	1.04338
1249	5.5732	30095.49	23932.05	0.7952
1250	5.6343	30425.25	43207.47	1.42012
1251	3.463	18700.25	23471.07	1.25512
1252	6.7915	36674.14	32622.01	0.88951
1253	1.7152	9262.3	25129.39	2.71308
1254	4.8976	26447.11	50622.51	1.9141
1255	7.9122	42726	43674.69	1.0222
1256	21.1044	113963.6	120108.66	1.05392
1257	30.1681	162907.99	46807.1	0.28732
1258	15.9333	86040	34356.49	0.39931
1259	20.057	108307.96	26841.56	0.24783
1260	3.8325	20695.37	23013.01	1.11199
1261	19.2673	104043.35	111986.59	1.07635
1262	30.5789	165125.81	96502.1	0.58442
1263	20.1338	108722.27	104805.29	0.96397
1264	27.3842	147874.68	85841.01	0.5805
1265	23.213	125350.37	96331.67	0.7685
1266	20.4099	110213.66	103797.58	0.94179
1267	10.994	59367.56	78099.14	1.31552
1269	7.5291	40657.35	39172.92	0.96349
1270	22.6466	122291.86	77452.6	0.63334
1271	12.7058	68611.29	.	.
1273	19.7151	106461.68	63003.5	0.5918
1274	2.5489	13763.83	20497.56	1.48923
1275	3.7023	19992.55	43362.7	2.16894
1276	10.0173	54093.2	160921.1	2.97489
1277	13.9004	75062.15	70079.85	0.93362
1278	5.546	29948.45	41675.87	1.39159

1279	6.2597	33802.53	33905.99	1.00306
1280	10.5161	56786.94	62135.42	1.09419
1281	6.7409	36400.89	92786.5	2.54902
1282	8.7637	47324.1	104016.99	2.19797
1285	2.8529	15405.49	.	.
1287	24.8054	133949.2	49785.97	0.37168
1288	17.3348	93607.72	.	.
1289	1.1782	6362.02	12124.1	1.9057
1290	12.0846	65256.67	60199.56	0.9225
1291	3.0605	16526.96	17209.6	1.0413
1292	3.3416	18044.47	20472.67	1.13457
1293	4.5889	24780.16	23743.77	0.95818
1295	2.9937	16165.72	18224.34	1.12735
1296	16.386	88484.44	126911.84	1.43428
1297	25.9156	139944.28	183877.24	1.31393
1299	14.6094	78890.64	161690.4	2.04955
1300	4.6879	25314.83	12801.26	0.50568
1303	8.361	45149.13	47424.86	1.0504
1304	34.2358	184873.36	150139.96	0.81212
1305	20.4821	110603.52	101594.62	0.91855
1306	14.6404	79058.08	142468.43	1.80207
1307	19.0184	102699.51	132334.73	1.28856
1308	6.6072	35678.64	25533.1	0.71564
1313	17.2356	93072.49	36711.54	0.39444
1319	18.1622	98075.87	21377.42	0.21797
1324	3.4232	18485.49	15191.94	0.82183
1327	6.7797	36610.48	71901.22	1.96395
1328	28.946	156308.23	196525.19	1.25729
1331	41.1555	222239.83	123205.34	0.55438
1332	40.3629	217959.48	157907.59	0.72448
1333	37.8517	204399.17	161531.34	0.79027
1335	18.6344	100626	87381.35	0.86838
1336	31.5673	170463.64	135181.81	0.79302
1337	20.7129	111849.55	125682.35	1.12367
1338	33.8101	182574.49	223788.81	1.22574
1339	55.6501	300510.39	238854.16	0.79483
1339	26.7601	144504.69	157343.09	1.08884
1340	6.3662	34377.72	29056.06	0.8452
1341	9.5049	51326.27	29196.11	0.56883
1342	6.6992	36175.74	31675.07	0.87559
1343	4.7402	25597.28	33153.77	1.29521
1345	6.9032	37277.49	23171.24	0.62159
1352	15.0254	81137.35	113343.28	1.39693
1353	26.6409	143861.13	138244.7	0.96096
1354	11.9223	64380.27	64779.02	1.00619
1355	38.8786	209944.21	167753.95	0.79904

1356	5.9689	32231.84	89625.6	2.78065
1357	10.3971	56144.26	71579.07	1.27491
1358	38.5857	208362.71	173366.41	0.83204
1359	29.0107	156657.62	107652.93	0.68719
1360	26.292	141976.73	162527.59	1.14475
1361	12.5712	67884.64	94883.52	1.39772
1362	13.7932	74483.24	28268.58	0.37953
1364	27.8746	150522.62	169700.16	1.12741
1365	6.8143	36797.22	55455.65	1.50706
1374	3.5778	19320.24	15064.82	0.77974
1375	4.7833	25830	19960.92	0.77278
1376	15.2611	82409.81	51472.93	0.6246
1379	12.2758	66289.38	54276.01	0.81877
1380	4.6013	24847.2	18534.05	0.74592
1385	26.4538	142850.68	138954.04	0.97272
1386	20.0017	108009.06	56926.44	0.52705
1390	29.539	159510.59	149337.33	0.93622
1393	5.4328	29337.1	27199.52	0.92714
1394	8.6417	46665.23	29700.37	0.63646
1395	7.4585	40276	76866.37	1.90849
1396	6.1394	33152.88	89657.47	2.70436
1397	17.9863	97126.11	140041.61	1.44185
1399	8.3656	45174.16	68014.27	1.5056
1402	1.3075	7060.27	23513.79	3.33044
1406	17.2741	93280.08	36678.29	0.39321
1407	21.2953	114994.83	59288.13	0.51557
1408	21.1241	114070.3	156308.48	1.37028
1411	7.2129	38949.84	21629.57	0.55532
1416	3.7058	20011.08	22651.09	1.13193
1417	6.555	35397.21	26522.03	0.74927
1418	22.1168	119430.81	67497.11	0.56516
1419	6.4501	34830.65	107399.25	3.08347
1420	7.6632	41381.18	86335.15	2.08634
1421	10.9776	59278.86	44865.14	0.75685
1422	22.3431	120652.6	105605.34	0.87528
1494	13.6032	73457.27	54273.57	0.73885
1495	8.7723	47370.21	58558.98	1.2362
1496	23.2147	125359.5	61097.89	0.48738
1501	12.0223	64920.16	88819.17	1.36813
1504	2.7337	14761.81	31797.06	2.15401
1506	20.2127	109148.74	117270.14	1.07441
1507	15.084	81453.86	83252.54	1.02208
1509	19.9736	107857.69	65558.93	0.60783
1510	21.1217	114056.97	92634.09	0.81217
1511	3.7265	20122.99	21482.38	1.06755
1512	7.4435	40195.01	41726.89	1.03811

1513	8.9874	48531.69	29243.85	0.60257
1520	25.8181	139418.01	91435.61	0.65584
1521	4.9795	26889.18	25132.6	0.93467
1523	2.3159	12506.08	12661.95	1.01246
1524	22.5355	121691.65	67161.19	0.5519
1525	18.4025	99373.49	96358.21	0.96966
1526	8.9429	48291.46	67519.69	1.39817
1527	2.8962	15639.63	19993.5	1.27839
1529	4.2794	23108.54	26560.34	1.14937
1531	1.3937	7525.96	20232.78	2.6884
1532	10.4447	56401.62	28836	0.51126
1533	18.8647	101869.2	69252.03	0.67981
1534	37.6806	203475.16	94857.04	0.46618
1535	12.8843	69575.32	.	.
1536	22.4308	121126.13	31887.75	0.26326
1537	48.4574	261670.09	102794.56	0.39284
1538	40.8981	220849.98	90408.69	0.40937
1539	45.7921	247277.14	119673.83	0.48397
1540	5.0374	27201.7	29481.66	1.08382
1541	16.6446	89880.88	64674.74	0.71956
1542	4.6636	25183.48	50075.16	1.98841
1543	14.2149	76760.25	210255.57	2.73912
1544	1.809	9768.82	18452.18	1.88889
1545	0.3122	1685.9	5363.43	3.18135
1546	14.4515	78038.36	106381.63	1.3632
1547	7.4688	40331.35	30610.49	0.75898
1547	4.2053	22708.79	22344.81	0.98397
1548	10.3886	56098.35	52442.27	0.93483
1550	6.8381	36925.74	61803.74	1.67373
1552	4.4182	23858.3	49576.32	2.07795
1553	3.8309	20687.04	39099.86	1.89007
1554	35.1856	190002	76672.15	0.40353
1555	33.3085	179866.04	93202.42	0.51818
1556	8.0889	43680.12	44950.53	1.02908
1557	5.3225	28741.34	.	.
1558	18.1383	97946.65	105231.19	1.07437
1558	5.2291	28236.87	43509.53	1.54088
1560	5.9416	32084.62	44196.04	1.37748
1561	16.1859	87404.07	92787.87	1.0616
1562	3.0629	16539.83	24126.9	1.45871
1563	19.859	107238.79	73263.07	0.68318
1564	8.288	44755.4	34940.87	0.78071
1588	6.0003	32401.79	20196.7	0.62332
1596	9.4339	50942.84	48969.45	0.96126
1597	11.0808	59836.08	64762.5	1.08233
1598	8.7705	47360.92	77150.08	1.62898

1599	4.1	22140.05	43877.94	1.98184
1605	20.4589	110478.25	111419.35	1.00852
1655	29.5429	159531.75	193448.45	1.2126
1656	12.1739	65738.89	64683.66	0.98395
1657	7.9742	43060.79	72656.64	1.6873
1795	9.6137	51914.16	30550.82	0.58849
1796	8.7653	47332.56	51621.59	1.09061
1797	11.5181	62197.65	39628.86	0.63714
1799	4.3346	23406.82	14378.3	0.61428
1800	37.061	200129.38	80011.95	0.3998
1800	6.9248	37393.71	21341.42	0.57072
1801	1.5462	8349.37	15589.34	1.86713
1802	0.1286	694.58	.	.
1804	15.8248	85453.94	137428.53	1.60822
1807	8.2846	44736.89	15930.34	0.35609
1809	39.746	214628.66	92053.95	0.4289
1810	12.1494	65606.7	51483.1	0.78472
1814	84.8195	458025.57	152980.43	0.334
1815	30.364	163965.79	70932.3	0.4326
1816	0.7572	4088.93	16854.34	4.12195
1826	3.0856	16662.38	16050.85	0.9633
1831	1.4153	7642.52	15558.02	2.03572
1832	0.4257	2298.85	19183.88	8.345
1833	2.6793	14468.12	33928.45	2.34505
1834	10.7782	58202.43	28566.26	0.49081
1835	7.2965	39401.01	47687.36	1.21031
1836	28.1122	151805.95	114957.88	0.75727
1837	22.6192	122143.79	104531.5	0.85581
1839	10.1501	54810.61	63741.86	1.16295
1841	10.9487	59123	.	.
1845	5.7817	31221.08	29175.43	0.93448
1846	14.7068	79416.66	26515.83	0.33388
1847	14.4517	78039.32	39497.03	0.50612
1858	4.8881	26395.67	21315.7	0.80755
1861	6.6639	35985.32	31599.54	0.87812
1862	5.084	27453.46	23319.45	0.84942
1866	15.2444	82319.89	85777.84	1.04201
1866	17.6676	95405.21	36184.37	0.37927
1867	2.0821	11243.54	29938.28	2.66271
1868	5.9355	32051.55	30414.56	0.94893
1869	5.1498	27809.18	26410.28	0.9497
1870	7.4419	40186.07	29026.96	0.72231
1872	6.4184	34659.32	28155.17	0.81234
1873	2.4461	13208.77	18699.56	1.41569
1874	4.0984	22131.55	19822.58	0.89567
1875	2.0147	10879.12	24227.63	2.22698

1876	9.0838	49052.35	29484.63	0.60108
1879	4.4427	23990.53	29143.73	1.2148
1883	0.4475	2416.49	15593.78	6.45306
1885	10.0627	54338.48	90162.26	1.65927
1886	26.5135	143172.71	.	.
1889	3.5299	19061.47	.	.
1891	30.6373	165441.58	114853.79	0.69423
1892	13.826	74660.39	89550.69	1.19944
1893	13.7764	74392.69	70462.74	0.94717
1894	2.2482	12140.24	29251.84	2.40949
1896	21.7742	117580.82	78481.23	0.66747
1897	17.1479	92598.88	89404.52	0.9655
1898	19.9244	107591.66	148393.62	1.37923
1904	19.2588	103997.6	103828.28	0.99837
1905	2.8421	15347.56	21193.69	1.38092
1906	17.2052	92908.01	87057.36	0.93703
1909	6.313	34090.36	37088.8	1.08796
1910	14.7722	79769.93	101949.24	1.27804
1911	7.6368	41238.89	84628.16	2.05214
1912	9.1392	49351.57	.	.
1913	5.509	29748.74	47094.5	1.58308
1914	10.1425	54769.29	125325.48	2.28824
1915	25.2594	136400.9	131899.14	0.967
1916	6.7591	36499.3	22823.81	0.62532
1917	32.4822	175403.64	85492.8	0.48741
1918	19.9483	107720.58	74732.81	0.69377
1919	35.0402	189217.25	135355.5	0.71534
1920	37.0741	200200.32	108860.14	0.54376
1921	27.1757	146749.05	113811.55	0.77555
1924	43.8995	237057.41	.	.
1925	13.2602	71605.03	46476.68	0.64907
1926	12.471	67343.39	52446.64	0.77879
1927	9.6609	52168.92	37732.03	0.72327
1928	17.32	93528.1	89712.55	0.9592
1929	9.9707	53841.89	49073.86	0.91144
1930	19.2709	104063.02	81644.53	0.78457
1931	26.6127	143708.84	128494.35	0.89413
1932	10.8257	58458.58	51157.84	0.87511
1933	6.6632	35981.2	44629.82	1.24037
1934	8.4388	45569.26	17357.08	0.38089
1935	23.2565	125585.05	23338.95	0.18584
1936	24.8552	134218.05	22373.93	0.1667
1937	21.7455	117425.85	120270.73	1.02423
1938	13.0914	70693.47	79979.74	1.13136
1939	30.8586	166636.69	137073.89	0.82259
1940	24.4605	132086.73	151149.21	1.14432

1941	37.295	201393.23	171614	0.85213
1942	6.1855	33401.84	81261.12	2.43283
1943	13.0341	70384.14	.	.
1944	9.1199	49247.58	93822.78	1.90512
1946	3.3367	18018.37	21361.61	1.18555
1947	9.103	49156.03	91862.05	1.86878
1948	12.6871	68510.51	72523.53	1.05858
1949	8.2822	44723.86	.	.
1950	8.1491	44005.01	35376.35	0.80392
1952	38.2749	206684.52	133678.29	0.64677
1953	49.1993	265676.42	177034.73	0.66635
1954	7.8513	42396.78	25233.96	0.59519
1955	10.524	56829.5	31133.08	0.54783
1957	3.2	17280	33348.05	1.92986
1960	21.4995	116097.27	42380.12	0.36504
1961	29.7534	160668.51	246193.4	1.53231
1968	19.7783	106803	132879.02	1.24415
1973	15.3836	83071.29	40964.71	0.49313
1974	12.1005	65342.86	43693.24	0.66868
1975	5.8743	31721.26	78646.87	2.47931
1976	6.781	36617.22	.	.
1977	9.1885	49617.99	91102.61	1.83608
1980	12.9656	70014.09	63166.15	0.90219
1981	8.8753	47926.48	28289.27	0.59026
1982	14.212	76744.98	77094.31	1.00455
1983	13.4036	72379.51	.	.
1994	8.5306	46065.24	22107.66	0.47992
1995	19.1464	103390.37	100530.87	0.97234
1997	20.0163	108088.15	102350.99	0.94692
1998	12.4277	67109.55	136950.62	2.0407
1999	13.261	71609.51	196955.36	2.75041
2000	14.4229	77883.48	194288.58	2.49461
2001	11.3621	61355.18	218554.26	3.56212
2009	5.295	28592.91	20553	0.71881
2010	5.8835	31770.78	24109.49	0.75886
2018	3.0778	16620.07	25340.47	1.52469
2019	19.7585	106696.13	86789.53	0.81343
2020	8.5097	45952.52	49276.61	1.07234
2021	1.7347	9367.58	21552.52	2.30076
2022	16.5334	89280.38	149334.72	1.67265
2023	15.3352	82810.15	138728.1	1.67525
2024	8.2034	44298.51	50593.49	1.1421
2025	6.2285	33633.78	40006.29	1.18947
2027	8.5271	46046.45	82998.34	1.80249
2028	15.4478	83417.99	96811.24	1.16056
2029	21.5322	116273.63	94823.33	0.81552

2030	11.1286	60094.22	47672.37	0.79329
2031	17.9464	96910.3	144033.5	1.48626
2032	15.0131	81070.97	110193.15	1.35922
2033	9.5627	51638.37	40067.61	0.77593
2036	15.4543	83453.35	130897.9	1.56852
2037	7.9028	42675.01	24119.87	0.5652
2038	11.3022	61031.71	61266.96	1.00385
2039	25.0721	135389.3	149247.77	1.10236
2041	14.1738	76538.49	100116.87	1.30806
2042	22.8637	123464.18	33441.52	0.27086
2043	12.233	66058.41	75852.31	1.14826
2045	15.627	84385.97	64360.03	0.76269
2046	19.2581	103993.92	73211.03	0.70399
2047	9.8448	53162.06	25510.99	0.47987
2048	6.3584	34335.3	31555.13	0.91903
2049	9.8215	53036.11	109092.17	2.05694
2050	10.7286	57934.23	95613.93	1.65039
2051	6.3617	34353.1	65728.33	1.91332
2052	14.0023	75612.45	93403.52	1.23529
2182	27.0862	146265.63	118934.86	0.81314
2185	43.9182	237158.33	187808.07	0.79191
2188	41.8284	225873.23	121023.84	0.5358
2189	56.7747	306583.55	161388.05	0.52641
2191	12.3915	66914.15	78154.56	1.16798
2195	14.3675	77584.4	152561.73	1.9664
2196	23.9628	129399.05	163323.99	1.26217
2197	22.9284	123813.48	138492.69	1.11856
2198	26.7249	144314.34	172551.84	1.19567
2199	19.025	102734.96	52960.33	0.5155
2200	6.223	33604.28	30832.12	0.91751
2202	29.5921	159797.24	52794.61	0.33038
2204	2.349	12684.69	49878.82	3.93221
2205	4.0531	21886.5	47486.44	2.16967
2213	0.7564	4084.58	30357.94	7.43233
2222	45.415	245240.96	.	.
2223	15.1286	81694.51	112694.61	1.37946
2225	11.058	59713.04	95380.15	1.59731
2226	25.679	138666.49	197764.82	1.42619
2227	12.5091	67549.05	44038.75	0.65195
2228	3.7394	20192.72	19408.56	0.96117
2229	3.0128	16269.04	64566.1	3.96865
2230	5.3771	29036.13	48333.92	1.66461
2231	12.3203	66529.58	90306.92	1.35739
2232	8.727	47125.88	95855.15	2.03402
2233	5.5984	30231.55	136222.24	4.50596
2234	5.8045	31344.24	76406.76	2.43766

2235	4.0047	21625.38	37187.42	1.71962
2237	4.3765	23632.9	23446.14	0.9921
2238	3.7072	20018.83	21643.64	1.08116
2239	66.9283	361412.91	195686.2	0.54145
2239	7.2283	39032.59	40708.71	1.04294
2240	28.234	152463.7	117168.1	0.7685
2241	13.5591	73219.13	55462.87	0.75749
2242	8.8216	47636.49	43861.01	0.92074
2245	28.6476	154697.17	103294.14	0.66772
2247	7.8671	42482.38	44961.78	1.05836
2248	9.7788	52805.72	111960.28	2.12023
2251	18.4239	99489.25	160464.92	1.61289
2252	30.8516	166598.88	144423.71	0.86689
2255	22.4042	120982.54	98733.53	0.8161
2256	27.1127	146408.51	95412.85	0.65169
2257	7.9252	42795.89	39290.31	0.91809
2258	13.4085	72406.12	89245.06	1.23256
2259	7.3557	39720.99	43936.65	1.10613
2260	7.7924	42078.94	83573.6	1.98611
2261	3.7226	20101.98	24476.39	1.21761
2262	14.811	79979.61	108892.67	1.36151
2263	14.9457	80706.74	108020.99	1.33844
2270	26.9371	145460.41	107146.07	0.7366
2273	12.9888	70139.75	111205.41	1.58548
2275	25.3732	137015.2	129764.5	0.94708
2277	56.4123	304626.58	381780.32	1.25327
2281	69.8569	377227.48	132065.92	0.3501
2283	37.3917	201915.19	108273.47	0.53623
2285	14.858	80233.16	97321.89	1.21299
2286	9.0192	48703.51	88534.59	1.81783
2289	18.3839	99273.33	48363.93	0.48718
2290	62.2633	336221.67	115911.5	0.34475
2291	86.665	467990.85	151786.67	0.32434
2297	19.0373	102801.6	92759.26	0.90231
2303	13.4416	72584.79	66127.35	0.91104
2312	7.2401	39096.62	37152.4	0.95027
2313	37.6538	203330.6	132336.24	0.65084
2314	58.9703	318439.79	172012.24	0.54017
2315	62.5971	338024.18	131709.09	0.38964
2374	16.2239	87608.81	39678.81	0.45291
2375	15.901	85865.23	49339.27	0.57461
2378	10.2508	55354.08	101724.97	1.83771
2379	7.8658	42475.25	125849.08	2.96288
2380	11.0777	59819.67	47783.19	0.79879
2381	8.734	47163.69	38166.58	0.80924
2382	5.5607	30027.53	31745.1	1.0572

2383	10.5975	57226.71	51083.51	0.89265
2384	5.8123	31386.49	36504.46	1.16306
2386	11.1305	60104.86	41696.53	0.69373
2387	12.2843	66335.12	51469.62	0.7759
2389	20.4495	110427.52	88025.01	0.79713
2390	7.2088	38927.73	34436.1	0.88462
2391	21.4185	115660.17	90360.25	0.78126
2392	13.8865	74987	106116.67	1.41513
2395	12.749	68844.83	54391.95	0.79007
2396	12.9977	70187.55	125166.45	1.78331
2397	6.835	36909.11	66806.21	1.81002
2398	8.0959	43718.04	101110.61	2.31279
2407	8.901	48065.13	53503.48	1.11315
2408	15.4016	83168.61	104585.57	1.25751
2409	8.561	46229.39	93097.56	2.01382
2410	10.7194	57884.65	28288.97	0.48871
2411	2.558	13812.95	.	.
2412	3.2486	17542.62	22344.03	1.2737
2413	7.6036	41059.51	102156.2	2.488
2414	10.173	54934.1	89065.88	1.62132
2415	10.8066	58355.78	103091.28	1.7666
2416	3.8218	20637.87	13513.96	0.65481
2417	8.6846	46896.91	.	.
2424	0.5694	3074.69	3398.09	1.10518
2429	16.424	88686.96	111603.98	1.2584
2436	76.816	414806.43	233715.74	0.56343
2437	10.385	56080.31	154659.82	2.75783
2439	19.004	102619.69	53863.64	0.52489
2440	30.523	164822.67	135882.56	0.82442
2444	73.814	398597.31	317162.55	0.7957
2447	21.378	115439.58	81365.93	0.70484
2449	34.403	185777.86	88282.97	0.47521
2450	50.547	272954.33	116545.12	0.42698
2452	32.888	177596.63	47293.1	0.2663
2476	91.363	493360.83	170862.19	0.34632
2496	148.492	801859.32	282276.47	0.35203
2502	16.105	86964.99	97757.6	1.1241
2502	2.381	12855.85	15181.22	1.18088
2503	0.831	4485.31	.	.
2504	15.164	81887.27	111069.17	1.35637
2504	4.503	24316.95	26014.63	1.06981
2505	21.238	114683.06	161127.42	1.40498
2505	19.264	104027.55	84151.17	0.80893
2506	38.167	206101.49	189135.7	0.91768
2506	71.586	386563.29	198978.86	0.51474
2507	75.134	405721.04	195052.94	0.48076

2508	39.065	210949.2	203099.12	0.96279
2509	17.631	95204.74	200851.01	2.10967
2511	14.069	75971.6	77861.47	1.02488
2513	0.172	926.58	.	.
2514	20.084	108456.15	78482.06	0.72363

Variable	N	Mean	Std Dev	Minimum	Maximum
SEARAT	1245	1.2878809	0.2433956	1	3.1116029
DAYTRAIN	1245	5.6306791	5.9042303	0	82
DAYSWITC	1245	1.2514839	1.4209648	0	17
NITETHRU	1245	5.0254167	5.2070438	0	48
NITESWIT	1245	0.7220921	1.0676355	0	9.5
TIMETBLS	1245	38.412865	13.903793	1.6156463	90
MINSPEED	1245	17.625169	10.728404	0	50.65
MAXSPEED	1245	36.278668	13.783206	1.6156463	87.916667
MAINTRAK	1245	1.0006125	0.2952312	0	3
OTHERTRK	1245	0.5253188	0.4587141	0	5.160582
SIDSIZ	1245	0.3207987	0.7739354	0	10.33
ABS	1245	0.1609812	0.3312301	0	1
CTC	1245	0.3906006	0.4461154	0	1
MAN	1245	0.4071608	0.4603335	0	1
ROUTLEN	1245	41.098917	39.606689	0.16	376.01
SIDSUM	1245	0.5582338	1.1539737	0	10
TRAINLEN	1245	79.517119	350.05328	1.005849	6684.66
ALTCARM	1245	10.962401	1.0527988	5.8078942	13.764873
RRAMAIN	1245	0.1581439	0.0926257	0.00812	0.40378
RRSIDNG	1245	0.1079093	0.015973	0.07711	0.12803
MAINS	1245	1.1583987	0.3566876	0	3.3657
SIDINGS	1178	0.1079377	0.0177717	0	0.25598