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16. Abstract

The study explores the economic benefits and costs of clearing a West Virginia routing for the movement of double-stack railroad container equipment. Results suggest that, in addition to significantly shortening mid-Atlantic to mid-west shipping times, the project would open cental Appalachia to affordable domestic and international container service, thereby helping to spur economic development within the region.

The study, conducted in conjunction wit Norfolk Southern (NS) Corporation and a number of mid-Atlantic and mid-western states, examines the economic feasibility of expanding clearances along Norfolk Southern's mainline route between Norfolk, Virginia and a variety of mid-western cities. Work would include modifying 28 railroad tunnels located primarily in West Virginia. According to the study, the ability to use double-stack container equipment along the West Virginia routing could save shippers and their customers as much as $759 million over the life of the project. The present value of these savings is estimated to be $368 million. Associated construction costs should be in the area of $120 million.

The RTI study includes plans for the development of a truck/rail intermodal facility in western West Virginia. By significantly reducing the cost of moving containers to and from the region, the project would eliminate one of the principal barriers that isolates western Appalachia from many international markets. The proposed project could also provide useful additional capacity during times of congestion at mid-western intermodal facilities.

The study concludes by recommending that affected states undertake the preliminary engineering necessary to further refine project cost estimates and that these states also develop the formal relationships necessary to further pursue the project.

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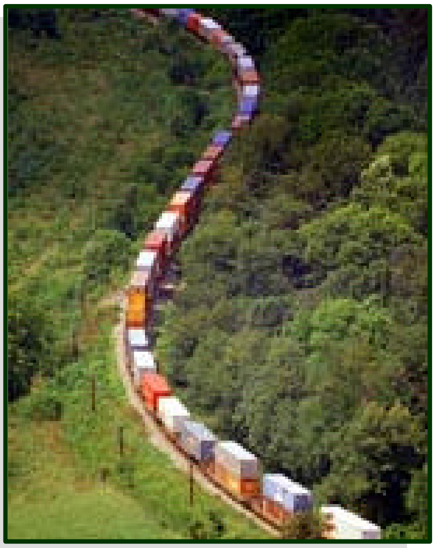
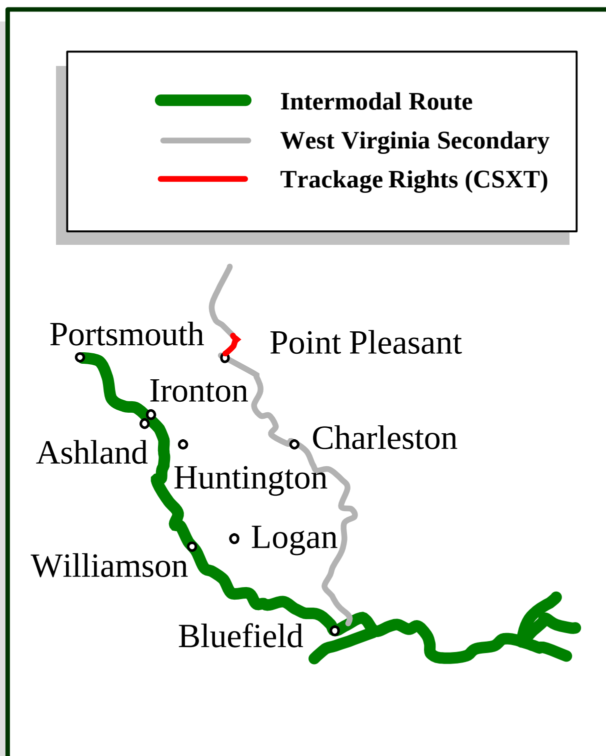
Central Corridor Double-Stack Initiative

FINAL REPORT





March 2003

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Executive Summary

E-1 Background and Motivation

The vast majority of manufactured commodities moving in international trade are shipped in ocean-going containers. Thus, except for locations relatively near seaports, regions that wish to engage in emerging global markets must rely on rail-truck intermodal facilities. The nearer manufacturers are to such facilities, the more competitive they are. Firms that are relatively far from intermodal facilities find it difficult to compete in international markets.

With the possible exception of West Virginia's northern and eastern panhandles, most areas of West Virginia are more than 130 miles from the nearest rail-truck intermodal facility (See Figure E-1). The same is true for eastern Kentucky and southern Ohio. This lack of proximity adds approximately $450 - $650 to each container shipped to or from the region. As a result, the volume of such shipments is relatively small.[1] If the region is to become a meaningful participant in international markets for manufactured goods, the lack of access to intermodal terminals must be addressed. However, because the rail lines that traverse the region cannot accommodate double-stack intermodal railroad equipment, remedying the lack of facilities is challenging.

Freight containers are shipped most efficiently when they are moved in equipment that allows containers to be stacked two high (double-stacked). Double-stacking allows many quasi-fixed train costs to be spread over a nearly doubled cargo capacity. This substantially reduces the per-ton cost of container movements. Generally, double-stacks require a minimum top-of-rail clearance of 20'3".

Within this context, the West Virginia Department of Transportation, in conjunction with a number of partners, has engaged in an analysis that explores the feasibility of modifying existing railroad trackage so that rail routes within the region can accommodate double-stack container movements.[2] The section

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[1] See *Transportation and the Potential for Intermodal Efficiency Enhancements in Western West Virginia: Phase I*, Center for Business and Economic Research, Marshall University, June, 2000.

[2] Partners include the Appalachian Regional Commission, the Federal Highway Administration, the Ohio Rail Development Commission, the Commonwealths of entucky and Virginia, the West Virginia and Norfolk Southern Corporation.

Figure E-1
Existing Intermodal Locations
(Direct-Served by Class I Carriers)

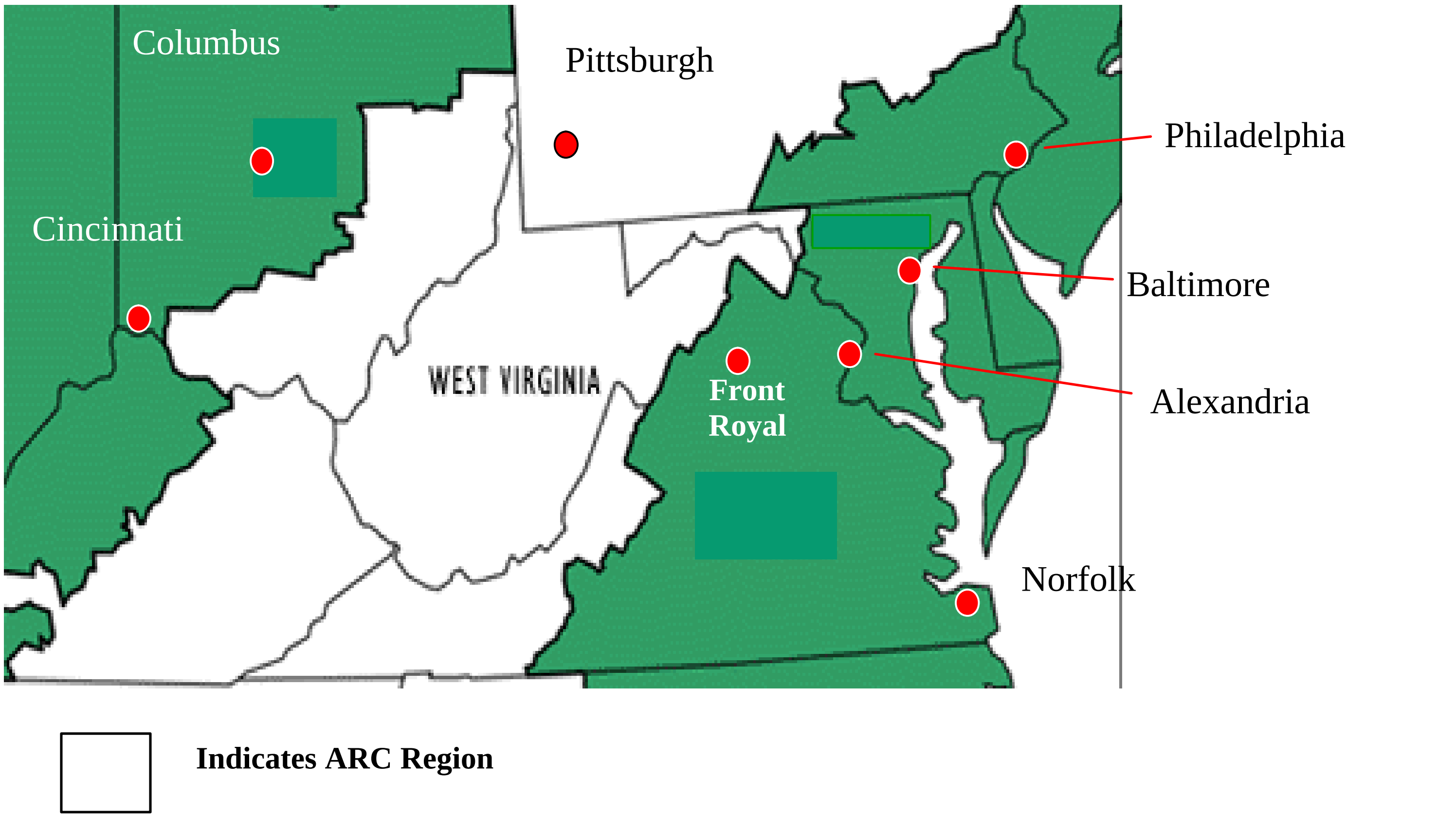
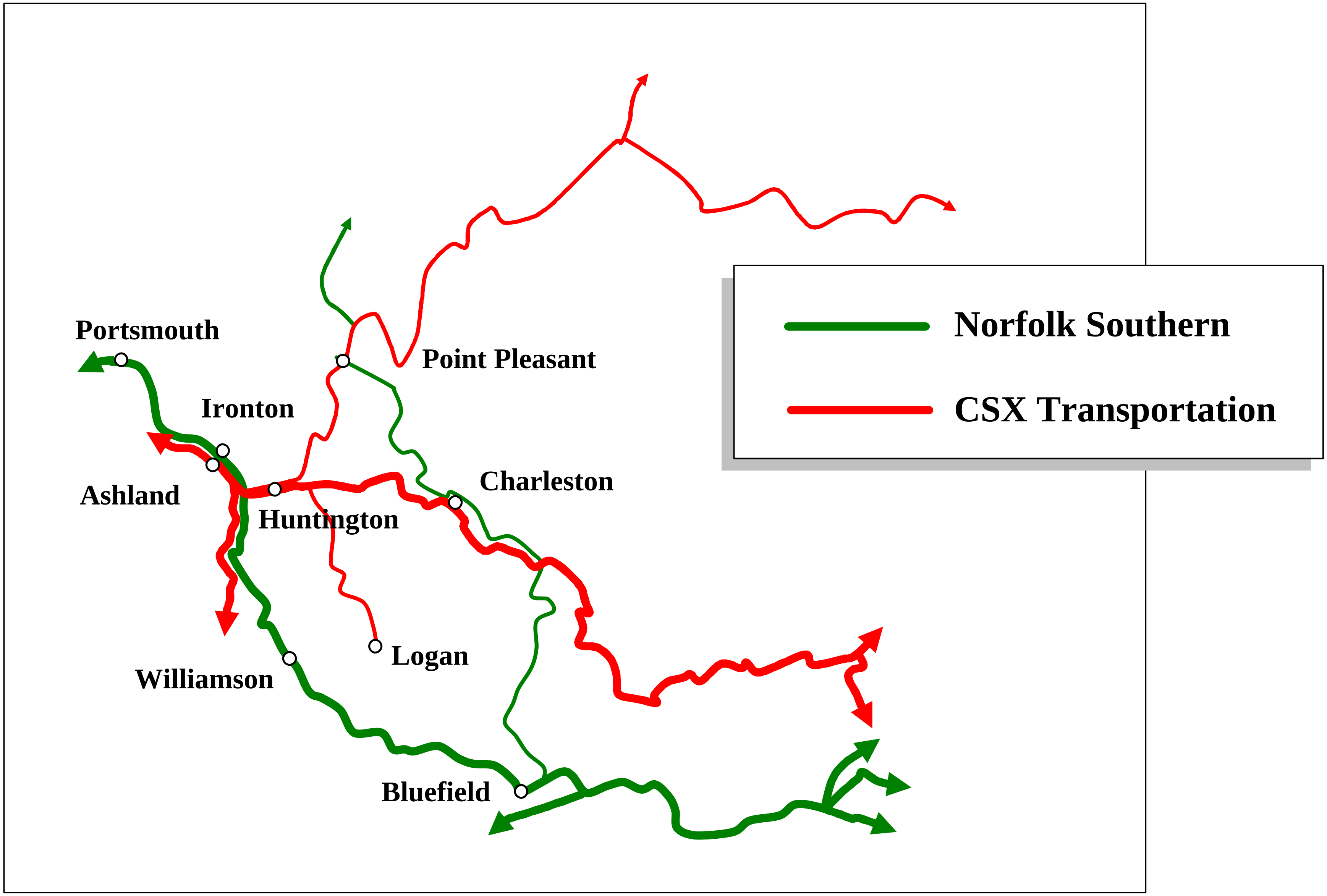


Figure E-2
Regional Rail Network



that follow summarize the preliminary findings of this investigation and provide a set of policy recommendations.

E-2 Regional Rail Infrastructure

Figure E-2 illustrates the Class I railroad trackage operated in West Virginia, southern Ohio and eastern Kentucky. There are five main routes, of which four could potentially be used to connect central Appalachia with the east coast and mid-western markets.

Norfolk Southern (NS) operates the former Norfolk & Western (N&W) route that originates in Virginia, before traversing southern and western West Virginia en route to Ohio and a variety of other mid-western states. NS also operates a secondary mainline that leaves the N&W route at Kellysville, West Virginia, heading north-westerly across the state through Charleston and Point Pleasant, West Virginia en route to Columbus, Ohio.

CSX Transportation (CSXT) operates three primary routes within the region. The first of these is a north-south route through eastern Kentucky. This route holds little potential to enhance regional access to international markets. The remaining two routes are generally east-west in nature and could, therefore, be used to link central Appalachia to container markets along the east coast and in the mid-west.

The first of the CSXT routes is the former Chesapeake & Ohio (C&O) route from Virginia, through southern and central West Virginia (including both Charleston and Huntington) en route to Cincinnati. CSXT also operates a secondary mainline from Virginia, through Grafton and Parkersburg, West Virginia to a connection with the former C&O mainline at Huntington.

Of the four potential east-west routes, none offers clearances that are sufficient to accommodate double-stack equipment. Lengthy tunnels represent the primary impediment. However, bridges and overhead wires also restrict the height of the equipment that can be safely moved over these routes.

E-3 Route Selection

Both NS and CSXT were invited to participate in the current investigation. However, CSXT declined to take part. Thus, the study has focused on identifying the most efficient NS routing through the study region.

The carrier’s West Virginia Secondary through Charleston and Point Pleasant features fewer feet of tunnels and more opportunities for eliminating existing tunnels altogether. Unfortunately, there are other characteristics associated with this line that would significantly increase the cost of using this route for container traffic. These factors include, but are not limited to: (1) a general lack of signals; (2) a lack of passing sidings; (3) grades that would significantly impact the horse power necessary to move intermodal trains at efficient speeds; and (4) track alignment obstacles that might make it impossible to accommodate trailer-on-flat-car (TOFC) or auto-carrying equipment.[3]

Norfolk Southern's former N&W routing contains as much as 30,000 feet of tunnels that would require modification to accommodate double-stack equipment.[4] However, the other characteristics of this route are generally compatible with intermodal movements. The vast majority of the route has two main tracks. Moreover, there are numerous sidings that can be used to meet and overtake other trains. The entire route is signaled and controlled by Centralized Traffic Control (CTC) and alignments are such that the route can be (and is currently) used for TOFC and automobile traffic.

Based on its comparison of the two NS routes the study team recommended in the fall of 2001, that the initiative focus exclusively on the former N&W route during the remainder of the investigation. After carefully evaluating this proposal, the project's Steering Committee accepted it, suspending further consideration of the West Virginia Secondary.

E-4 Study Region Terminal Facilities

Simply routing additional container traffic through West Virginia would do nothing to improve the region's access to intermodal transport. Accordingly, NS has agreed that, as a component of the overall project, it would construct and serve a mechanized rail–truck intermodal terminal within the study region.

While no definitive action has been taken, a preliminary site for the terminal has been identified at Prichard in Wayne County, West Virginia. This location offers a number of important features including, but not limited to: (1) current NS ownership of much of the necessary property; (2) easy roll-through access to mainline trackage; (3) close proximity to Interstate 64 via US 52; and (4) a very limited number of proximal residential structures.

Importantly, the study team and Steering Committee investigated a number of alternative locations, including a site at Kenova, West Virginia near where NS and CSXT mainlines cross.[5] Such a location might potentially be served by both railroads. This possibility, combined with the fact that a Kenova facility would be even closer to Interstate 64 than the Prichard location, at first made Kenova quite attractive.

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[3] There are two 16 degree curves that may or may not accommodate longer rail cars. This is important because TOFC and automobile movements are often combined with container traffic in the make-up of trains. There appears to be no feasible way to mitigate this concern.

[4] Available documentation indicates that there are 29 tunnels which total nearly than 30,000 feet in length where some clearance issue exists. The actual extent of the obstructions cannot be discerned absent additional engineering work.

[5] In addition to examining potential terminal locations of their own choosing, the study team also solicited recommendations from local development officials.

Unfortunately, there are a number of factors which seriously disadvantage a Kenova site. These include, but are not limited to: (1) significant and costly operational challenges associated with NS access to such a facility; (2) the need to acquire and raze a number of both residential and commercial structures; (3) the close proximity of a number of remaining residential properties; and (4) a clear lack of both economic incentive and physical ability on the part of CSXT to serve such a facility.

This last factor is very important. Readers will recall that CSXT has no immediate interest in clearing its route for double-stack movements to the east. Moreover, without the base provided by through east-west traffic, it would be unable to provide economically competitive services from Kenova to the west. Hence, even if CSXT were provided access to a regional facility, it is highly unlikely it would serve it.

Based on these factors, in April of 2002 the study team recommended that the initiative suspend further consideration of the Kenova location. After careful discussion, the Steering Committee agreed.

Again, no formal steps have been taken to adopt the Prichard site. It is, however, strongly representative of the type of facility that would likely be constructed to serve western West Virginia, eastern Kentucky, and southern Ohio. A simplified drawing of an intermodal terminal at the Prichard site is included here as Figure E-3.

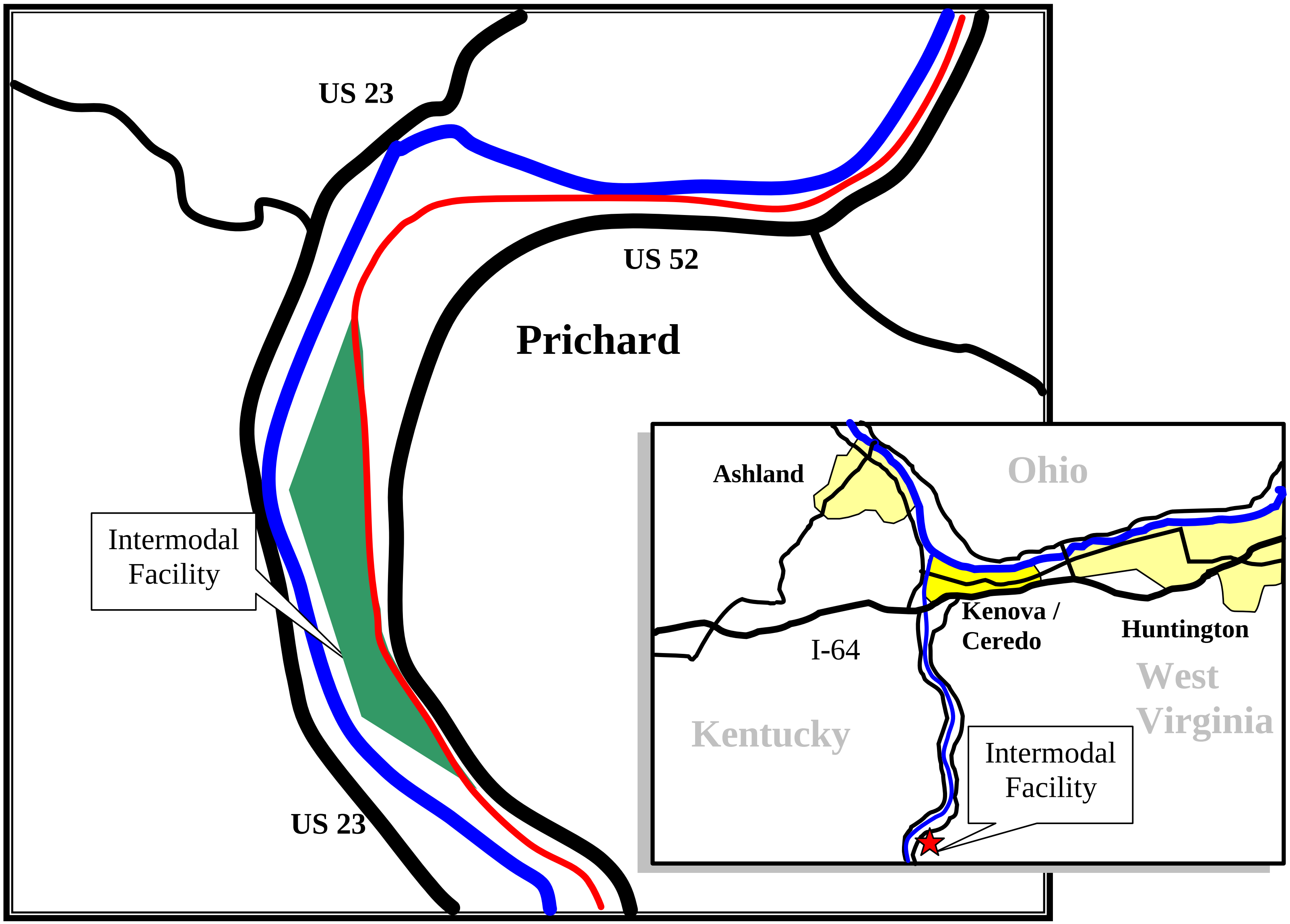
Rahall Transportation Institute (RTI) economists used yearly data describing the economic and demographic characteristics of a broad cross-section of metropolitan areas to estimate the volume of intermodal container traffic that would likely be observed at a Wayne County facility. Estimation results are contained in Table E-1.

Table E-1.

Estimated First-Year
West Virginia Container Traffic

	To	*From*	*Total*
Norfolk	3,416	2,294	5,710
Chicago	2,412	714	3,126
Detroit	438	2,352	2,790
TOTAL	6,266	5,360	11,626

Figure E-3
Prichard, West Virginia Terminal Location



Based on a five-day per week schedule, these estimates translate into roughly 45 total (inbound and outbound) containers each day.

E-5 Estimated Project Costs

As noted above, the 28 tunnels that would require modification represent the largest obstacle. There are, in fact, a variety of methods that can be used to alter these structures so that they provide the desired clearance.[6] These methods include: (1) eliminating the tunnel by removing all overburden (daylighting); (2) undercutting and lowering the tunnel floor; (3) liner removal excavation and liner replacement; and (4) notching tunnel liners to achieve additional clearances.

Table E-2 summarizes estimated project costs. The actual process of obtaining additional clearances would likely involve the use of each of these methods at various locations, depending on the physical characteristics and geological conditions observed at each specific tunnel site. Unfortunately, modification costs vary widely depending on which method is used, so that it is difficult to narrow the range of potential costs. For example, if all desired clearances were obtainable through tunnel notching, the cost of clearing the 28 tunnels, as well as other route obstructions, would bee approximately $43 million. Alternatively, if the traditional NS method of liner removal and excavation is necessary at every location, total project costs would exceed $111 million.

Cost estimates for the liner removal and excavation methodology were developed by Norfolk Southern and confirmed by RTI. Cost estimates under the remaining methods were developed by RTI and reviewed by NS.

In the absence of preliminary engineering information describing the conditions at each tunnel location, it is not possible to further refine these cost estimates. However, the study team is confident that the actual project cost would fall within the range of values presented here.

Table E-2
Estimated Costs

	N&W Route (Maximum Notching)	*N&W Route (No Notching)*
Tunnel Costs	$43.3 M	$108.4 M
Other Infrastructure Costs	$2.7 M	$2.7 M
Total Costs	$46.0 M	$111.1 M

[6] In most settings, 20’3” is considered sufficient clearance for the movement of double-stack containers.

E-6 Project Benefits

Traditionally, transportation projects have been judged on the basis of the welfare-enhancing cost reductions they generate. The proposed project would reduce actual transportation costs in four ways. First, containers currently moving between Norfolk and the mid-west via West Virginia in a single stack configuration would be double-stacked.[7] Second, double-stack traffic that now moves between Norfolk and the mid-west via a Harrisburg routing would move to the West Virginia routing, reducing the total shipment by approximately 120 – 300 miles (depending on mid-west location). Third, central Appalachian shippers who currently must truck containers over distances of as much as 500 miles, could reduce costs significantly by substituting a truck-rail movement. Finally, because transit times for current double-stack traffic would be reduced by one and one-half days, the inventory costs faced by shippers would also fall.

The efficiency gains and related cost reductions would be divided among a wide variety of beneficiaries. Certainly, NS would profit from these savings. However, markets where truck-rail movements compete are extremely competitive. Hence, it is likely that most of the savings would pass through to shippers and their customers.

RTI developed estimates of project benefits based on the cost savings described above. Actual values were based on currently observed traffic volumes, the expected growth in intermodal traffic over a 20-year time horizon, and cost parameters developed through the use of NS-specific data supplied on an annual basis to the Surface Transportation Board.

RTI considered a number of scenarios in which rates of intermodal traffic growth varied and in which NS routed varying quantities of Norfolk-midwest traffic to the West Virginia routing. Over the past decade, container traffic through US ports has grown at an average annual rate of 6.5 percent. The associated standard deviation from this mean is 2.0 percent. Accordingly, traffic growth was modeled at the mean and at one standard deviation above and below that value. The growth rate for NS container traffic has exceeded the national average for each of the last six years.

All values reflect the present value of a 20-year benefit stream. Out-year benefits were discounted at a real rate of 6.125 percent. Reported values are in 2000 dollars. Estimated benefit values are summarized in Table E-3.

It is important to recognize that there are additional project benefits not captured within these calculations. For example, shorter transit distances mean measurably less fuel consumption and pollutant emissions. Ultimately, this means less human exposure to pollutants and reductions in pollution related

[7] NS currently operates one train per day in each direction between Norfolk and Chicago that carries single-stack containers. This traffic consists of extremely time-sensitive shipments of high-valued commodities for which the reduced transit times justify the significantly higher transportation costs.

healthcare costs. These savings are not reflected here. To the extent that creating new rail capacity keeps rail traffic from diverting to the highways, the project is also likely to reduce the need to expend federal and state funds on road construction. Reducing rail to highway diversions also reduces roadway congestion delays and the probability of vehicle collisions. These additional benefits are very real. Unfortunately they are very difficult to calculate. Readers should note, however, that the benefit values currently used within the analysis substantially understate the actual value of the proposed project.

Table E-3.

Estimated Project Benefits
(Present Value over a 20 year time horizon. Discount Rate = 6.125%)

Traffic Base	*4.5% Annual Growth in Intermodal Traffic*	*6.5% Annual Growth in Intermodal Traffic*	*8.5% Annual Growth in Intermodal Traffic*
Norfolk – Columbus, Norfolk – Chicago	$201 million	$239 million	$288 million
Norfolk – Columbus, Norfolk – Chicago, Norfolk – Detroit	$216 million	$258 million	$311 million
Norfolk – Columbus, Norfolk – Chicago, Norfolk – Detroit, plus West Virginia Traffic	$256 million	$305 million	$368 million

E-7 Regional Economic Development Benefits

The approximately 11,000 annual containers projected for the West Virginia intermodal facility upon its opening largely reflect the diversion of all-truck traffic to a rail-truck routing. Most of these containers are already entering the study region. However, the 11,000 figure does not reflect the potential growth in traffic associated with new regional economic development.

Figure E-3 illustrates the potential service region for a Prichard intermodal facility. This figure is based on a Euclidean distance of 100 miles. Actual highway distances and travel times are provided in Table E-4. For many cities, an intermodal facility at Prichard would represent a potentially valuable new resource capable of supplying highly competitive truck-rail services. Ashland, Huntington, and Ironton would easily constitute local drays. Competitive drayage rates would also be likely for Charleston, Williamson, and Portsmouth as long as traffic levels are sufficient to provide regular back-haul opportunities. Even Logan, Morehead, and Pikeville may find it possible to benefit from the Prichard facility.

It is important to realize that many of the other elements necessary for the effective use of a new intermodal facility – most notably developable property and good highway access – are readily available in the region. The Prichard site lies above the 100-year flood plane in the Big Sandy River basin and is notably flat in comparison to other areas of the region. Moreover, there are similar properties on the Kentucky side of the Big Sandy and across the Ohio River in the state of Ohio.

As noted above, the Prichard site has ready access to Interstate 64 via US 52. Interstate 64, in turn, connects with other major components of the interstate system through interchanges with Interstate 75 at Lexington and Interstate 77 and 79 at Charleston. From Prichard, motor carriers can reach a number of major commercial centers via the Interstate highway system without encountering congestion at the origin or at intermediate points along the route. Table E-5 summarizes a few such opportunities.

The combination of usable land, rail-truck facilities, and direct highway access to various prominent destinations suggests that the development of an intermodal facility at Prichard would open significant opportunities for new regional product distribution activities. Again, the availability of competitively priced intermodal transport does not guarantee that these distribution activities or other likely forms of economic development would emerge. However, the absence of such facilities *does* guarantee that they will not.

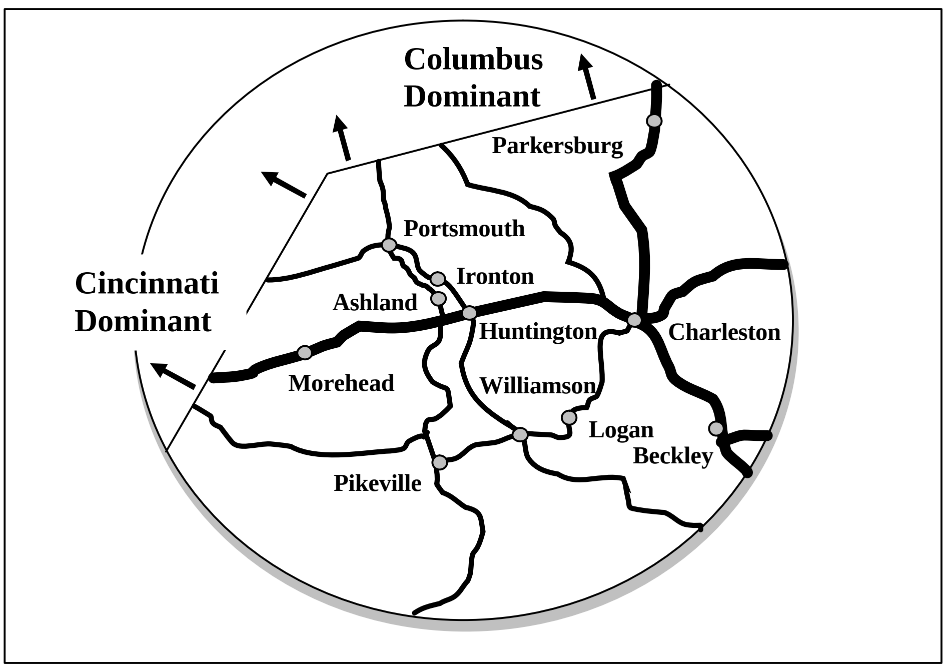
Table E-4
Study Region Highway Distances to Prichard, WV

From	*Distance to Prichard, WV*	*Distance to Columbus, OH*	*Distance to Cincinnati, OH*	*Travel Time (Hrs – Mn)*
Ashland, KY	22	125	140	0 – 33
Beckley, WV	131	221	310	2 – 16
Huntington, WV	24	139	206	0 – 32
Ironton, OH	27	119	132	0 – 38
Logan, WV	72	217	311	1 – 36
Morehead, KY	73	152	142	1 – 14
Parkersburg, WV	147	110	201	2 – 27
Pikeville, KY	85	227	221	1 – 47
Portsmouth, OH	53	91	116	1 – 06
S Charleston, WV	67	157	246	1 – 12
Williamson, WV	59	203	216	1 – 11

Table E-5
Regional Access

City	*Distance to Prichard, WV*	*Largest Intermediate Point*	*Travel Time (Hours-Minutes)*
Charlotte, NC	338	Charleston, WV	5 – 25
Cincinnati, OH	216	Lexington, KY	3 – 18
Cleveland, OH	321	Charleston, WV	5 – 14
Knoxville, TN	275	Lexington, KY	4 – 36
Louisville, KY	206	Lexington, KY	3 – 21
Nashville, TN	347	Lexington, KY	5 – 39
Pittsburgh, PA	300	Charleston, WV	4 – 59
Richmond, VA	388	Charlottesville, VA	6 – 12
Washington, DC	430	Charleston, WV	6 – 52
Winston-Salem, NC	283	Charleston, WV	4 – 46

Figure E-4
Regional Access



E-8 Summary and Recommendations

Based on the project benefits and costs as presented here, the benefit-cost ratio for the proposed project lies somewhere between 1.8 and 5.9.[8] Under the most extraordinarily conservative assumptions regarding traffic growth and project costs, the investment required to open the NS route to double-stack container movements and develop an intermodal facility that serves the study region are amply justified. As these assumptions are relaxed to reflect more likely outcomes, the double-stack initiative emerges as a remarkably promising transportation and economic development project. This conclusion is echoed by a report recently released by the American Association of State Highway and Transportation Officials (AASHTO) in which the current project is identified as one of three multi-state rail projects capable of yielding significant public benefits.[9]

The conclusion that the proposed project is economically justified suggests that it is appropriate to consider the subsequent steps necessary to bring the initiative to fruition. The most immediate need is for additional engineering studies. These studies will yield the definitive cost information needed in the funding process. They will also help to identify any heretofore undiscovered challenges that are likely to be encountered in the tunnel modification process.

From a regional standpoint, it is also important to design an economic development program that makes good use of the planned intermodal facility. Again, the facility opens a number of opportunities, but in and of itself guarantees nothing. Even while the facility is in its design stage, policy-makers should begin to explore how newly created access to affordable intermodal transport can be used to attract new commerce. This exploration must consider ownership issues, as well as how the facility would be managed and marketed. It should also catalogue nearby developable properties (identify existing infrastructure water, sewer, power, etc) and note the ways in which the transportation project can complement already ongoing regional development activities.

As a final note, observers must appreciate that the approach pursued in the investigation of these proposed intermodal projects reflects a fundamental departure from the traditional means of infrastructure development. Historically, federal, state, and local governments have developed roadways, while private firms have developed railroad facilities.

However, the mix of public and private interests in the proposed improvement to regional rail lines and intermodal facilities reflects two important realizations. First, there are often benefits to transportation projects that extend well beyond the private gains that may accrue to individual firms. Thus, private

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[8] The lower bound does not include West Virginia traffic, so that the projected West Virginia terminal costs are not included in the calculation. The upper bound *does* include West Virginia traffic, so that terminal costs *are* included in the calculation.

[9] See *Transportation: Invest in America Freight-Rail Bottom Line Report*, American Association of State Highway and Transportation Officials. January 2003.

interests cannot be expected to supply an optimal quantity of such facilities. Instead the public sector must be a willing participant in joint infrastructure development projects regardless of who owns the physical facilities. This realization has motivated a number of public-private partnerships similar to the current study effort.

Second, transportation planning is more effective when all modes are considered collectively within an overall system analysis. This latter realization has driven the movement toward true intermodalism evident over the last 10 years. Again, however, the West Virginia Double-Stack Initiative is a laudable example of the productivity that results when planning efforts span multiple transport modes.

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1.Introduction and Study Overview

1.1 Regional Study Context

In the fall of 1999, West Virginia's Department of Transportation, in conjunction with the Appalachian Regional Commission and a number of State Development Districts, initiated an examination of transportation flows, infrastructures, and practices in the western portion of the State.[10] This study was performed by Marshall University's Rahall Transportation Institute (RTI) Among the study's many findings was the observation that container shipping to, from, and within the region is virtually nonexistent. Given the prevalent linkage between containerized shipping and international trade, this finding is not surprising. West Virginia exhibits a relative paucity of international commerce, ranking 40th among all states in the percentage of Gross State Product that is tied to exports.

Further study revealed that both the small volume of international shipments and the associated lack of container traffic is probably linked to the relatively high costs faced by West Virginia shippers who wish to move goods by container. Most locations within the State are approximately 500 miles from east-coast seaports. In such a setting the rail / truck intermodal movements of containers could possibly represent the preferred modal combination. Unfortunately, there are no rail / truck intermodal facilities within West Virginia, so that shippers wishing to use containers must either truck shipments the entire distance from east coast ports or pay significant drayage charges from rail facilities in Cincinnati, Columbus, or Pittsburgh.[11] For west-coast movements, where all-truck moves are usually unaffordable, use of an out-of-region rail facility is generally the only viable alternative. In nearly every case, the result is the same – West Virginia firms (as well as firms in southern Ohio and eastern Kentuccky) face shipping costs that are $450 - $650 per container higher than the cost faced by competitors in locations having locally available rail / truck container services.[12] In most international markets, a cost disadvantage of this magnitude is prohibitive.

To be very clear, the addition of an intermodal facility to the State's inventory of transportation infrastructures does not guarantee an increase in the volume of international trade and a resulting growth in container movements. However, the lack of such facilities *does* virtually guarantee that no such increase in international commerce will be forthcoming.

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[10] This project also benefited from support by the Federal Highway Administration.

[11] Evidence suggests that the few West Virginia shippers who do use containers usually employ truck-only routings.

[12] See *Transportation and the Potential for Intermodal Efficiency-Enhancements in Western West Virginia*, Rahall Transportation Institute, Marshall University, November 2000. Within the current context, "local" means within a distance of 50 – 75 miles from the intermodal facility.

The ability of a West Virginia intermodal facility to positively affect the volume of international commerce depends on the extent to which such a facility could erase the current competitive disadvantage faced by the region's producers. At present, it would be possible to develop a facility that handles both international and domestic containers shipped in a "single-stack" railroad configuration.[13] Single-stack service is, however, very costly, offering only a minimal rate advantage over all-truck movements. The ability of regional firms to effectively compete with other mid-west and mid-Atlantic producers depends on creating affordable regional access to *double-stack* container shipping.

Currently, the double-stack movement of containers through West Virginia is made impossible by clearance restrictions on CSXT and Norfolk Southern (NS), the two Class I rail carriers that serve the State. Thus, while the aforementioned RTI study recommended the in-region development of double-stack service as a possible remedy to lagging international commerce, it is impossible for the State to act unilaterally on this suggestion. Instead, any attempt to pursue improved intermodal service must be the product of a public-private partnership involving the appropriate governmental entities and, at least, one privately held railroad.

1.2 National Transportation Context

Historically, transportation planners focussed on individual transport modes. Over the past decade, however, mode-specific attentions have given way to efforts to efficiently combine disparate modes in ways that provide transportation users with more flexibility and, at the same time, make better use of available transportation capacities. This latter approach has received the generic label of *intermodal* transportation.

In concept, intermodal transport is not new. For centuries, cargoes have been transloaded from maritime vessels to land-based vehicles for further movement and, even now, most cities bear the remnants of "freight houses" where railroad shipments were transloaded to trucks for final delivery.

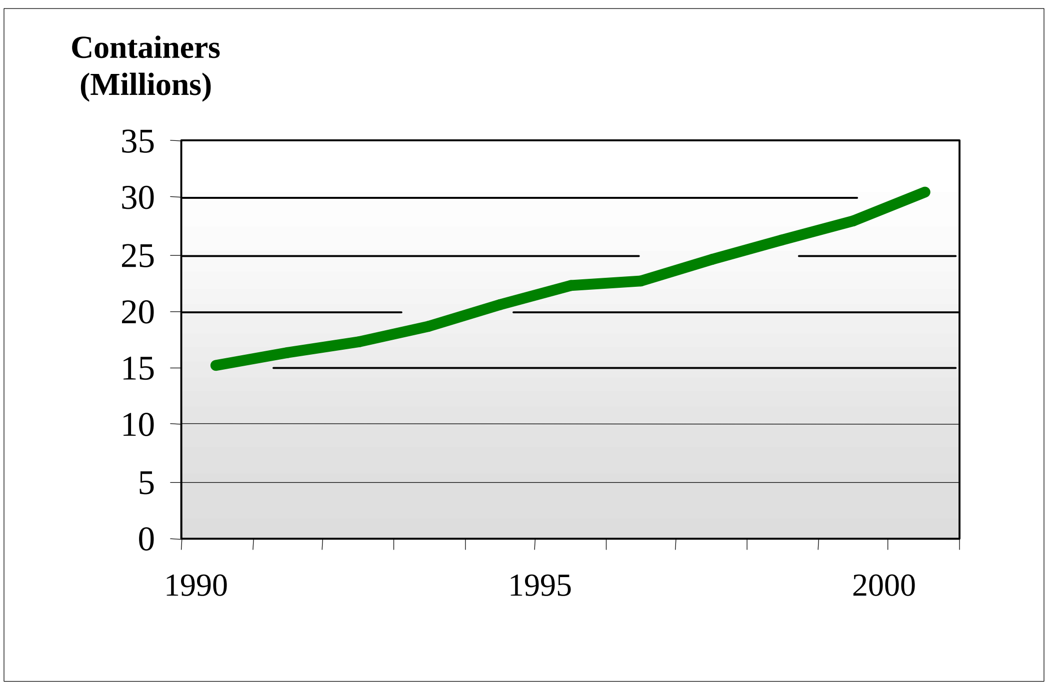
The recent focus on intermodal is made novel by its design and purpose. Historically, two or more modes were seldom used when a single mode could provide the required service. It was deemed inefficient to incur transload costs when they might otherwise be avoided. However, in recent decades, transportation practitioners have succeeded in significantly reducing the costs of moving cargoes from one mode to another, so that it is now possible to efficiently combine transport modes. This ability has become important to planners as mode-specific capacities are exhausted in some locations.

[13] In the railroad intermodal container system, a position where a container may be placed on a rail car is called a platform. Current intermodal rail cars have up to five platforms. If containers are stacked two-deep on a platform, the configuration is called double-stacking. Double stacking is highly desirable by the railroads, as it effectively doubles the capacity of the train without a corresponding increase in track space or crew requirements.

Initially, the current generation of intermodal transportation was anchored in the movement of (truck) trailers on (railroad) flat cars (TOFC). TOFC movements continue to be an important component of the North American transport network. Nonetheless, the intermodal movement of trailers has been eclipsed in volume by the movement of containers on flat car (COFC).[14] Containerized shipping is particularly prevalent in international shipping, where ocean going container movements are combined with truck and / or rail for the land-side leg(s) of the routing.[15]

The use of containers in international commerce has grown precipitously over the past decade. This growth is depicted graphically in Figure 1.1. Container traffic over US ports has grown at an average annual rate of 6.5% since 1990. As international container traffic has grown, so has the railroad movement of containers. For example, over the same 10-year period, Norfolk Southern's container traffic has grown at an annual rate of over 8%. Finally, the rapid growth in container traffic is projected to continue unabated for the foreseeable future. The US Department of Transportation's Maritime Administration projects that container movements over US ports will grow by four million units per year over the next 10 years.[16]

Figure 1.1
Container Volumes Over US Ports



[15] Over the past few years, other intermodal combinations have emerged. For example, inland navigation is now occasionally used to position both empty and loaded international containers.

[16] See, "Avoiding Clogged Arteries," *Traffic World*, July 9, 2000, p. 99.

The transportation system's ability to accommodate the projected growth in intermodal shipping will require additional capacity. Already, the federal government, as well as state and local jurisdictions, have devoted resources to significant new infrastructure projects designed to meet this need.[17]

1.3 The Current Study Effort

Initially, West Virginia's Department of Transportation (and later its other project partners) sought the cooperation of both CSXT and NS in the further investigation of the probable costs and benefits of creating railroad clearances that are sufficient to accommodate double-stack container movements through West Virginia and southern Ohio. After participating in early discussions, CSXT ultimately elected to forego further participation in the study. Thus, the current effort has focussed on estimating the benefits and costs of modifying a NS routing.

The current study began in the Spring of 2000. The effort has been directed by a steering committee comprised of state representatives from West Virginia, Ohio, Kentucky, and Virginia and participants representing the Appalachian Regional Commission, and Norfolk Southern Corp. The research has received financial support from the states of West Virginia and Ohio, the RTI, Norfolk Southern and the Federal Highway Administration

The ongoing research effort represents a reconnaissance-level investigation intended to assess the economic feasibility of improving NS rail infrastructure so that it accommodates double-stack movements. This has required the completion of seven specific tasks. These tasks are summarized in Table 1.1.

In an environment where both public and private resources are scarce, all proposed projects are subject to considerable scrutiny by those who seek alternative uses for available funds. Recognizing this fact, the study team has sought to develop highly defensible estimates of probable outcomes. To do so, the team has often adopted the most conservative approach available when making assumptions or selecting parameters. At very least, the study presents outcomes under a range of possible alternative assumptions.

1.4 About Public-Private Partnerships

As the federal government moves toward the reauthorization of the current surface transportation funding bill a variety of constituencies are lauding the use of public-private partnerships as a vehicle for creating new transportation infrastructures. As with the current focus on intermodal transportation, combining public funds with resources from private sources represents a relatively new method of capacity development.

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[17] Consider, for example, the double-stack clearance project on former Conrail trackage in Pennsylvania or the recently opened Alameda Corridor in southern California – both projects that combined public and private resources

Table 1.1
Study Tasks

Tasks
Selection of best NS route
Evaluation of current clearance restrictions
Assessment of methods / costs of eliminating restrictions
Identification of site(s) for West Virginia facility
Estimation of regional economic development benefits
Measurement of national economic efficiency gains
Consideration of equitable financial participation

From an economic vantage, there are two legitimate motivations for pursuing public-private cooperative efforts. First, there are instances in which market imperfections lead privately held concerns to invest sub-optimal amounts in transportation facilities.[18] In such cases, the overall efficiency of the nation's transportation system can be improved through public intervention. Secondly, specific regions can measurably improve their competitiveness by *accelerating* the development of transportation capacities.[19] While such impacts may largely represent the relocation of existing economic activity, they are, nonetheless important from a regional perspective.

The preliminary analysis summarized in the current document suggests that clearing a West Virginia routing for double-stack rail traffic would measurably improve the efficiency of the nations' transport network, yet there is every evidence these improvements will not occur without public involvement. The analysis also suggests that providing western West Virginia, southern Ohio, and northeastern Kentucky with affordable access to truck / rail intermodal service could create meaningful new opportunities for additional commerce. Thus, the current public-private investigation of this project appears justified under both economic criteria

[18] These market imperfections include the incidence of public goods, capital market imperfections, the existence of natural monopoly, and the presence of market externalities.

[19] Limited stocks of available capital and the concept of opportunity cost suggest that firms may find it necessary to forego some profitable investments until other *more* profitable investments have been completed.

2.Engineering Assessment

2.1 Route Selection

Figure 2.1 depicts Norfolk Southern's two routes through West Virginia. The principal line is the former Norfolk and Western (N&W) mainline, which extends from Norfolk, VA through Roanoke, VA and on to Columbus and Cincinnati, OH. The second route combines the former Virginian Railway line between Kellysville, WV and Deepwater, WV and a former Conrail (ex-New York Central) line connecting Deepwater and Columbus, OH.

The former N&W mainline, hereafter referred to as the Pocahontas mainline, is a key component of Norfolk Southern's overall route structure. East of Bluefield, the line is part of the NS Virginia Division, serving as a high capacity link for coal and merchandise moving to Mid-Atlantic points. West of Bluefield, the route lies in the NS Pocahontas Division. Besides handling significant overhead merchandise traffic, this portion is a major originator of coal traffic. As such, it is one of the heaviest tonnage routes in the NS system. In 2001, portions of the Pocahontas mainline handled in excess of 80 million gross tons (MGT) of traffic per year. Train volumes exceed 50 per day at some locations, especially in the mining district.

Because of its importance and high traffic levels, the Pocahontas mainline has received tremendous capital investments. The route is predominantly double tracked, with only short sections of single track remaining. Numerous crossovers permit train movement between the main tracks, and frequent sidings provide additional flexibility. The entire route is equipped with a block signal system, and many miles operate under a centralized traffic control system. Much of the line in West Virginia follows river courses, resulting in gentle grades. The mountain divides between river valleys have the steepest grades on the route, but realignments over the years have resulted in a route with the most favorable grade and curvature for the terrain.

From the east, the Pocahontas mainline's major entrance into West Virginia is at Bluefield. It then skirts the state's southern border, passing through Welch and Williamson en route to Kenova, where it crosses the Ohio River. From a junction at Portsmouth, OH, traffic can move north to Columbus or west to Cincinnati. Both cities provide connections to other NS routes.

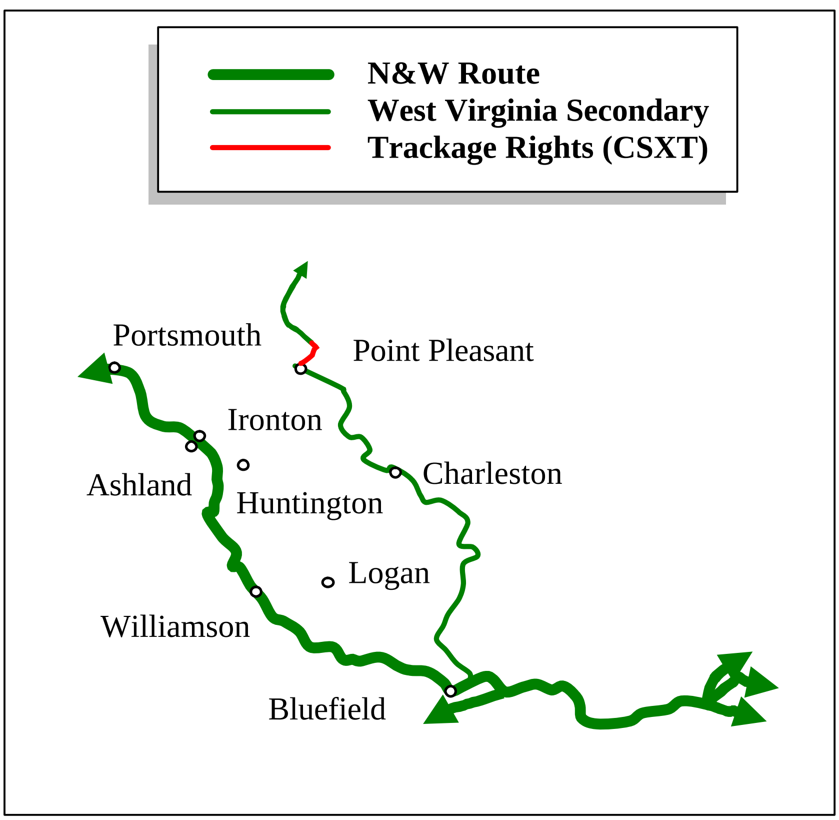
The former Virginian Railway diverges from the Pocahontas mainline at Kellysville, WV. This line, built to haul West Virginia coal to tidewater Virginia, heads north through Princeton and Elmore to Deepwater. From Deepwater, the former Conrail West Virginia Secondary, acquired by NS in 1998, continues through Charleston, WV to Point Pleasant, WV, where it crosses the Ohio River. On the Ohio side of the river, the route enters a short stretch of CSX owned trackage before heading north again on NS-owned right-of-way to Columbus, OH.

The Kellysville-Deepwater-Columbus route, which this report will refer to in its entirety as the West Virginia Secondary, has historically not handled a large volume of through traffic. The former Virginian railway was designed to gather West Virginia coal and move it south and east to Norfolk. With the decline of business in recent years, NS retired many sidings, removed double track, and partially deactivated the signal system. While well engineered, the line's profile and alignment were not designed for high speed operation. Because of the mountainous terrain it penetrates, the line has numerous tunnels and tall bridges.

The former Conrail line traditionally handled the movement of coal and industrial traffic from central West Virginia to Columbus, OH and beyond. This section of the route does not traverse rugged terrain and is generally moderate in terms of grade and curvature. However, it has few passing sidings and is not equipped with a signal system.

Along most of the West Virginia Secondary, train volumes average 4-6 daily. Between Elmore and Columbus, tonnage levels in 2001 were well under 7 MGT. Coal accounts for a substantial portion of the business on the route, though the industrial basin along the Kanawha River is an important traffic source. Although physically a through route, the West Virginia Secondary does not at present handle any through trains. Traffic moving between the former Conrail and Virginian portions of the route is almost exclusively coal related.

Figure 2.1
Norfolk Southern Trackage



Theoretically, either NS routing could be cleared to accommodate double-stack movements. However, after a careful assessment, the study team suspended consideration of the West Virginia Secondary and focussed all attentions on the former N&W routing This decision was based on the following issues.

Infrastructure Modification Costs Ignoring the relevant incremental costs of signals, sidings, and other track work, the West Virginia Secondary is very competitive in terms of clearance enlargement costs. While the route has a greater number of tunnels, the aggregate length of these tunnels is actually less than the total on the Pocahontas mainline. However, significant track and signal work *would* be necessary to upgrade the Secondary to provide the same level of service for double stack trains as the Pocahontas mainline. Under existing traffic forecasts, for the Secondary, NS has no need or plan to provide these improvements.

In 2001, NS estimated the cost of the required non-clearance improvements, including rail and tie replacement, surfacing, construction of additional sidings, installation of signals and power operated turnouts, to be $86 million. It may be possible to reduce these costs to some degree or to successfully argue that some portion of necessary expenditure would not be incremental to the planned intermodal service. Nonetheless, if even half of the estimated non-clearance infrastructure costs survive the analysis, the routing is no longer competitive.

General Operating Costs The N&W mainline routing is more favorable in terms of both alignment and grades than the West Virginia Secondary. The latter route has a rugged profile in West Virginia, with grades exceeding one percent common and curves of up to 16 degrees. Moreover, there are few opportunities available on the Secondary to improve alignments and grades without significant expense and environmental impact. Hence, the cost of operation would be measurably greater in terms of crews, fuel, and locomotive costs. Finally, while the West Virginia Secondary's alignment would accommodate double-stack equipment, there is some question as to whether or not it would allow the use of the longer intermodal equipment used to transport TOFC shipments.

Transit Times Without significant and costly track realignment, curvature and grade will limit train speeds on many portions of the West Virginia Secondary to 20-30 mph. In addition, the predominantly single track nature of the line increases the probability of traffic-related train delays, especially without infrastructure improvements. The Pocahontas main has higher overall speeds at present and is equipped with the double track and centralized traffic control needed to handle traffic efficiently. Upgrading the Secondary to meet the existing transit time of the Pocahontas main would be prohibitively costly.

Columbus Access The configuration of NS trackage in the Columbus area makes it difficult to access current intermodal facilities from the West Virginia Secondary. This difficulty is further amplified when one considers the potential need to access additional intermodal facilities in the southern portion of the metropolitan Columbus area. Alternatively, the Pocahontas mainline reaches the Columbus area from the south, providing direct access to both existing and potential intermodal sites. Better access, in turn, implies lower operating costs and improved transit times.

2.2 Clearance Obstructions

NS measured clearance envelopes along the Pocahontas mainline using automated equipment. During this process, the company identified restrictions to double stack movement. These included tunnels, overhead structures and wires, signals, wayside slide fences, and railway bridges. Company standards for double stack operation specify a vertical clearance of 20'-9" above the top of rail over a minimum width of 8'-6" centered on the track.

In opening the Pocahontas mainline to double stack traffic, NS expressed a strong desire to clear both main tracks. It would be possible to open a double stack route with only a single main track cleared. However, such an option provides much less operational flexibility than clearing both tracks. In addition, great care will have to be taken to ensure that double stack traffic is always routed via the cleared track. The infrastructure elements identified as clearance obstacles therefore cover both main tracks.

Table 2.1 summarizes the infrastructure elements, other than tunnels, that must be altered or removed to provide double stack clearances. In general, these are not difficult, from an engineering or construction standpoint, to address. The locations of the obstacles are at various points between Walton, VA and Columbus, OH.

The most difficult and costly restrictions to address are the tunnels. The Pocahontas mainline has 28[20] tunnels in need of clearance improvements to accommodate double stack containers. These tunnels are at 27 discrete locations between Walton, VA and Ft. Gay, WV. Two locations have separate tunnels for the two main tracks. Individual tunnel lengths vary, but most are less than 1,000 feet long. The tunnels total 28,861 feet in length.

Table 2.2 lists the tunnels and their measured characteristics. Design and construction documents and geotechnical drawings are, for the most part, non-existent. A search of the engineering department files revealed few drawings or documents related to the tunnels. The information in Table 2.2 was verified by a field visit to each location.

Tunnels sized for two tracks predominate, though some are only large enough for a single track. Three of the tunnels designed for double track presently contain a single track.

In cross section, the tunnels are similar, typically having a horseshoe shape. The typical tunnel crown is about 22 feet above top of rail. This height does not extend for sufficient width to permit double stacks to clear.

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[20] Of the 28 bores in need of modification, four are located in Virginia, one is in Kentucky, and the remaining 23 are in West Virginia.

Table 2.1
Non-Tunnel Clearance Obstructions

Milepost	*Location*	*Obstruction*	*Remedial Action*	*Cost*
N-351.95	Ingleside, WV	Slide fence	Adjust fence	$12,600
N-362.25	Bluefield, WV	Overhead bridge	Lower tracks 15"-16"	$1,305,234
N-363.65	Bluefield, WV	Overhead wires	Remove	$12,600
N-364.25	Bluefield, WV	Overhead wires	Remove	$12,600
N-378.64	Maybuery, WV	Thru truss bridge	Modify bracing	$38,000
N-378.64	Maybuery, WV	Thru truss bridge	Modify bracing	$38,000
N-379.10	Maybuery, WV	Slide fence	Modify fence	$12,600
N-399.90	Hemphill, WV	Slide fence	Modify fence	$12,600
N-402.92	Farm, WV	Thru truss bridge	Modify bracing	$38,000
N-402.92	Farm, WV	Thru truss bridge	Modify bracing	$38,000
N-406.10	Davy, WV	Slide fence	Modify fence	$12,600
N-418.30	Wilmore, WV	Slide fence	Modify fence	$12,600
N-434.50	War Eagle, WV	Slide fence	Modify fence	$12,600
N-446.50	Devon, WV	Slide fence	Modify fence	$12,600
N-462.30	Sprigg, WV	Thru truss bridge	Modify bracing	$38,000
N-467.20	Sycamore, WV	Slide fence	Modify fence	$50,000
NA-44.90	Pritchard, WV	Coal tipple	Remove tipple	$250,000
N-576.93	Coal Grove, OH	Thru truss bridge	Modify bracing	$37,800
N-576.93	Coal Grove, OH	Thru truss bridge	Modify bracing	$37,800
N-579.83	Ironton, OH	Overhead. Bridge	Lower tracks	$634,284
N-634.74	Glen Jean, OH	Thru truss bridge	Modify bracing	$1,638
N-651.77	Lunbeck, OH	Thru truss bridge	Modify bracing	$1,638
N-653.84	Lunbeck, OH	Thru truss bridge	Modify bracing	$9,324
N-683.96	Ashville, OH	Thru truss bridge	Modify bracing	$17,600
Various	Various		Misc. signal work	$125,000
TOTAL				**$2,648,718**

Most of the tunnels appear to have a reinforced concrete lining. The exceptions are two tunnels having a masonry lining and a single tunnel having no lining. Detailed information on the liner properties (e.g. thickness, strength) is not available.

Historical data indicates that the tunnel construction dates from the late 19th and early 20th century. The Pocahontas mainline was originally opened in late 1892. The original line west of Elkhorn, WV reportedly required but eight tunnels, so many of the existing tunnels must have been opened at a later date. A program to realign and double track much of the line, which took place in the early part of the 20th century, may have resulted in many of today's tunnels. The tunnels west of Naugatuck, WV (having an "NA" prefix on the milepost) were opened in late 1904 as part of a major relocation of the mainline. Pepper Tunnel (N 305.4), was built in 1900 for a line relocation. Cooper Tunnel was also created for an early 20th century line change. It is likely that all tunnels were periodically modified during the 20th century to accommodate larger equipment.

Table 2.2
Tunnel Clearance Obstructions

	Tunnel Name	*Milepost*	*State*	*Length (ft)*	*Tracks*	*Notes*
1	Pepper	N 305.4	VA	3,302	1	
2	Eggleston No. 1	N 316.2	VA	925	1	Built for 2 tracks
3	Eggleston No. 2	N 317.0	VA	1,195	1	Built for 2 tracks
4	Pembroke	N 319.8	VA	299	1	Built for 2 tracks
5	Cooper	N 374.3	WV	698	2	Masonry lining
6	West Vivian	N 392.1	WV	680	2	
7	Big Four No. 1	N 394.2	WV	645	2	
8	Big Four No. 2	N 395.1	WV	174	2	
9	Huger (No. 1 main)	N 395.6	WV	362	1	
10	Huger (No. 2 main)	N 395.6	WV	362	1	
11	Welch	N 398.9	WV	1,334	2	
12	Hemphill No. 1	N 400.2	WV	864	2	
13	Hemphill No. 2	N 400.4	WV	1,142	2	
14	Antler No. 1	N 403.7	WV	612	2	
15	Antler No. 2	N 405.1	WV	613	2	
16	Twin Branch No. 1	N 407.7	WV	760	2	
17	Twin Branch No. 2	N 408.1	WV	883	2	
18	Vaughn	N 412.1	WV	1,113	2	
19	Roderfield	N 413.1	WV	924	2	
20	Laurel	N 414.1	WV	803	2	
21	Gordon	N 415.1	WV	1,271	2	
22	Glen Alum	N 439.5	WV	1,302	2	
23	Hatfield (No. 2 main)	N 462.1	KY	997	1	Unlined
24	Williamson	N 471.6	WV	678	2	Brick lining
25	Big Sandy No. 1	NA 3.3	WV	2,627	1	
26	Big Sandy No. 2 (No. 2 main)	NA 6.0	WV	380	1	
27	Big Sandy No. 3	NA 6.8	WV	1,848	1	
28	Big Sandy No. 4	NA 12.7	WV	2,068	1	

2.3 Issues Related to Tunnel Clearance

Railway tunnels are employed to pass a track through ground which, for various reasons, cannot be economically removed. Locating engineers recommend tunnel construction only after a careful study of the economics of construction and operation. Tunnel construction is much costlier that an equivalent length of track on the surface. The tunnel represents a potential bottleneck to traffic, since expansion is difficult under operating conditions for increased traffic or larger vehicles. Furthermore, because subsurface condition can never be precisely determined in advance, tunnel construction (or modification) is risky.

Tunnel design controls include subsurface geologic conditions, required dimensions for track and equipment, and expected traffic volume. Budget also plays a role. Techniques used for tunnel excavation vary according to geologic conditions. In the Appalachian rock penetrated by the Pocahontas mainline, the bore face was typically advanced by controlled blasting followed by excavation of the loosened material. After a tunnel is bored, it may be left free standing if the ground has sufficient stability. More commonly, however, the interior must be lined with some material to prevent collapse and/or control the inflow of groundwater. Traditional lining materials include concrete, masonry, steel, and timber.

Most tunnels on the Pocahontas mainline are lined with concrete or masonry. This lining is a structural element that resists pressures exerted by the surrounding ground. The exact magnitude and distributions of these pressures are unknown. Disturbance of the lining without accounting for ground pressures risks tunnel damage or collapse.

Railway vehicles of the era when the Pocahontas mainline tunnels were built were small in comparison to modern equipment. The engineers of a century ago could not envision the clearance requirements of modern double stack cars, and they could hardly have justified the high cost of providing such generous clearances in tunnels. Thus, tunnel dimensions must be enlarged to permit the passage of double stack equipment.

Enlarging tunnels on an operating railroad, under traffic conditions, is a complex task. Seldom can the railroad afford to hold or reroute trains for long periods of time. The tunnel work would generally have to proceed during narrow work windows to permit train traffic to continue. At the end of each window, the conditions permit safe passage of trains. Unfortunately, this greatly increases the cost and time required to complete the work.

The following subsection discusses typical methods for accomplishing this clearance work.

2.4 Corrective Methods

There have been similar (though smaller in scope) projects to gain the clearances necessary for double-stack movements by enlarging tunnels. The Burlington Northern and the Canadian National undertook such projects in the early 1990’s and Conrail completed a Pennsylvania double-stack clearance project in 1995. Reports on these projects were obtained and examined as part of this study.

In rare cases, simply shifting the track position horizontally may provide the desired clearance. One example would be a tunnel designed for double track, but presently containing a single track offset from the tunnel centerline. Centering the track might provide the desired clearance with no additional modification to the tunnel or track structure. Eggleston Tunnel No. 1 (N 316.15) appears to be a candidate for this action, which is relatively low in cost.

Of methods for increasing clearances that involve modifying the tunnel structure, the six most common in current practice are:

- controlled blasting;
- scaling;
- liner removal and crown mining;
- notching;
- daylighting (tunnel removal); and
- track undercutting.

The appropriate clearance method in any particular setting depends a variety of factors, including existing tunnel dimensions, amount of enlargement required, liner type and thickness, depth of overburden above the tunnel, geologic conditions, budget, traffic volume, and reliability. The following sections describe the methods in more detail.

<u>Controlled blasting</u> In this method, explosive charges are used to enlarge the tunnel cross section. Holes are drilled in the tunnel perimeter at points where enlargement is desired. Charges are set in the holes and detonated to shatter the surrounding material. The process is repeated as necessary to obtain the desired dimensions.

Controlled blasting is generally favored for unlined tunnels. It presents some risks in that the blasts must be carefully controlled to prevent the removal of excessive material or even collapse of the tunnel bore. The method was not considered for the Pocahontas tunnels because most are lined.

<u>Scaling</u> Some tunnels have been successfully enlarged using a technique of scaling away a layer of material using hydraulic or air powered jackhammers or probes. The technique is especially useful in unlined tunnels, where certain types of rock respond well to such action. It may also be used in concrete or masonry lined tunnels, especially where the obstruction is localized.

Scaling is most cost-effective for small areas or when the depth of removed material is shallow. It is often used in conjunction with other methods. Because most of the tunnels examined in this study were amenable to more efficient methods of enlargement, scaling was not considered as a standalone method.

<u>Undercutting</u> By removal of underlying material in the track bed, or undercutting, the track may be lowered to increase the vertical clearance. Clearances provided by the undercutting operation may be further augmented by reducing the cross section of the track structure. In cases where the track is underlain by a granular material or friable rock, undercutting may proceed rapidly. Where the floor is sound rock, however, blasting or scaling is required to loosen the underlying material. In either case, since the track must be removed or, at a minimum, greatly disturbed, undercutting under traffic conditions must be carefully planned to minimize disruptions. Traffic volume is a significant factor in the productivity and cost of undercutting operations.

While simple in concept and used widely, undercutting must be performed with caution. Fixed objects, such as bridges or road crossings, near the tunnel end may control the elevation change achievable by undercutting.

Engineering standards limit the amount of track elevation change within a given distance. Undercutting of lined tunnels requires special precaution when the finished tunnel floor elevation is to be close to or below the foundation of the liner wall. Without the bracing effect of the floor, liner walls may be unable to resist lateral earth pressures. The result will be a displacement of the wall base in toward the tunnel centerline, reducing clearance and possibly leading to a collapse. To prevent this, the liner walls may be braced by various means. This adds significantly, however, to the disruption, cost, and time required to perform the undercutting operation.

Many of the tunnels on the Pocahontas mainline have already been undercut to the maximum extent possible without lowering adjacent structures or bracing liner walls. In at least one case, a tunnel had to be abandoned when liner walls collapsed inward at the base during undercutting. Given the heavy volume of traffic on the line, NS is reluctant to risk the disruptions and risk inherent with further undercutting.

Liner removal and crown mining Raising the roof of the tunnel is the alternative to lowering the track. In a lined tunnel, the roof lining must be removed to gain access to the rock face. Once exposed, this rock may be mined to obtain the necessary clearances. Once this is accomplished, the rock mass is reinforced using special bolts. Typically, a new liner is then created using sprayed on concrete, or shotcrete[21]. While this type of enlargement usually has a high unit cost, it often results in low long-term maintenance costs relative to some other methods. NS has used this method on previous tunnel enlargement projects, including the Montgomery Tunnel in Virginia (1990) and two brick lined tunnels in southern Indiana (1992).

Before the liner is removed, the geology of the surrounding ground must be investigated. Specifically, the rock type(s) and geologic structure(s) must be assessed in order to adequately predict the induced pressures, strengths, and stability. Detailed geological mapping is needed to show the location of different rock units are as well as their stratigraphy and structural features, the topsoil thickness, the composition of the slopes and the local state of subsurface water.

Test bores are performed from the ground surface, drilling down towards the tunnel crown. The bore samples reveal geological conditions around the tunnel. Drilling may also be performed from within the tunnel. Probe holes are drilled into the liner at a determined spacing. Cores reveal the liner thickness and composition. Rock samples confirm the state of geology behind the liner.

Before removal of the tunnel liner, rock behind the liner is typically injected with grout. Grouting solidifies granular materials and strengthens zones of weak rock. It also reduces groundwater inflow. As the tunnel bore must be free standing during the time the liner is removed and during the mining process, grouting provides an increased factor of safety against collapse.

[21] Shotcrete, a mixture of portland cement, aggregate, and water, is concrete applied by spraying.. For structural uses, shotcrete is usually sprayed over a framework of reinforcing bars and steel mesh.

Once material surrounding the existing lining has been stabilized, the roof portion of the liner is removed. Typically, the removal starts about 15 feet above the tunnel floor. Without the arch action of the roof to provide stability, the remaining side walls of the tunnel are often bolted to the surrounding rock mass. To further minimize the risk of collapse, the length of removed liner is typically limited to that which can be mined and replaced in a short period of time. One specification provided a 24 hour limit for removal, excavation, and replacement of the liner.

Excavation of the exposed tunnel roof may be performed by blasting, scaling, or other methods. The extent of enlargement depends upon the desired clearances and the thickness of the replacement liner, but is typically several feet.

Once the tunnel is excavated to the desired clearance, rock bolts are often used to provide reinforcement. Rock bolts secure individual rock blocks to the intact rock mass. The bolts also create a zone of compression in the rock mass, promoting arch action. A field engineer working alongside an excavating crew determines the spacing, size, location and angle of each bolt.

Finally, a replacement liner is applied. In tunnel sections in unstable ground, formed steel lining backed by injected concrete or grout may be installed. In the absence of such concerns, shotcrete is the preferred lining material because of its ease of application and rapid hardening. The material can be used as either a temporary or permanent liner. When used as a permanent liner, shotcrete is applied in layers to achieve the desired thickness. To minimize track time, shotcrete supplies and equipment are often rolled into the tunnel on special work trains. While advantageous, the operation of such trains require careful coordination with the railroad.

<u>Notching</u> Many tunnels have sufficient vertical height at the crown, but need minor modifications in the roof cross section to provide adequate clearance width for doublestacks. In such cases, it may be possible to notch the roof corners to ensure the necessary vertical clearances. Frequently, the notches are relatively shallow in extent, often much less than the liner thickness. In such cases, liner removal and crown mining is unnecessary.

In the notching process, longitudinal grooves are cut in the tunnel roof to establish clearances. The technique is applicable to concrete and masonry lining and to unlined tunnels. In lined tunnels, removal of the lining is generally unnecessary, a significant advantage over crown mining. Even if the required notch penetrates the lining, roof bolts may serve to secure the remaining lining to the tunnel walls.

A high-speed rock grinder is used to carve the notch to the desired. The grinding head is capable to cutting through concrete, reinforcing bar, and rock. As the head is mounted on an extensible boom, it can be placed at the desired location where cutting is needed. Adjustments to the boom control the depth and pattern of cut. The apparatus is mounted on a vehicle and rolled down the tunnel to create the desired notch. The depth of cut during a pass is controlled by the cutting head size and speed, vehicle speed, and lining properties. A vehicle mounted template shows the cutting head operator the required notch location and depth. If necessary, multiple passes are made to develop the desired notch dimensions. Debris from the cutting process falls into a dump truck or railcar beneath the cutting head, simplifying cleanup and minimizing track fouling. A high volume fan blows dust from the process away from the working area.

One advantage of notching is that all the apparatus may be mounted on trucks or construction equipment fitted for dual highway and rail (hy-rail) operation. When a train needs to pass through the tunnel, the equipment can be easily rolled down the track to a nearby grade crossing and quickly be taken off of the track. If no grade crossing is available, a temporary one may be created by laying timbers between and adjacent to the rails. In comparison, rail mounted equipment must be moved down the track to a siding, possibly a number of miles away. In heavy traffic territory where track time is limited, such as the Pocahontas mainline, the time savings and resulting increase in work productivity for using hy-rail equipment is significant.

In double track territory, notching has another important advantage. Traffic can pass on one track while the notching equipment occupies the other track. Unlike the other processes, like crown mining, the notching process is usually not disruptive enough to present risks to the passage of trains during the work. The work is simply suspended for the duration of the train's passage on the other track and resumed once the train is clear. This allows notching to continue at high rate of productivity, with much less impact on train traffic than other methods. Since the majority of the tunnels on the busy Pocahontas mainline are double-tracked, notching is an attractive option.

One significant issue associated with notching is whether the notch will fully penetrate the tunnel lining. An examination of the tunnel cross-section profiles along the Williamson routing indicates that the majority of the tunnels need only a few inches of liner removed at the notch points to obtain the desired clearance envelope. These tunnels are good candidates for notching. The remaining tunnels are more questionable; the notch may or may not fully penetrate the tunnel liner depending upon the liner thickness, which is presently unknown.

Available literature describing the notching method does not describe the effects of fully penetrating the tunnel liner. This creates considerable uncertainty regarding how the structural integrity of the liner would be affected under such a circumstance. To address this concern, the surrounding rock mass could be strengthened and the remaining liner segments tied to it. One approach would be to inject grout into the rock behind the lining. Rock bolts may then be employed to tie the remaining lining sections to the rock mass.

During a typical notching operation, a field engineer working alongside the crew would indicate where to place rock bolts and inject grout. Many tunnels could be notched without this additional reinforcement. However, to be conservative, the analysis presented in this report assumes both reinforcement / support techniques in the cost estimates for notching. Thus, these estimates represent an upper bound for expected costs.

Daylighting Daylighting is the complete removal of the tunnel overburden and liner. In essence, daylighting leaves the track in a deep cut, permanently eliminating clearance problems. During the process, overburden is progressively excavated from the ground surface to the liner. The liner remains freestanding until all overburden has been removed along the length of the tunnel. Thus, there is a minimal impact on train operations. Then the liner is removed section by section in a manner to minimize train delays.

Daylighting may be an option for some tunnels because advances in blasting and earthmoving technology make deep cuts much more practical today than in the era when the tunnels were built. Cuts several hundred feet deep are not uncommon in modern highway construction in Appalachia.

Although daylighting eliminates clearance problems, is not a panacea. Slope stability, drainage, and snow and ice removal are significant concerns in deep cuts. Furthermore, daylighting may require the purchase of additional right-of-way and have possible environmental consequences related to the disruption of wildlife habitats and disposal of overburden. Existing surface land uses will be impacted. Provisions for existing highways, pipelines, and other facilities to cross the open cut may add to the project cost. Access to the tunnel site for haul roads may require negotiation with adjacent property owners.

The cost of daylighting is roughly proportional to the depth of overburden above each tunnel. The larger the quantity of overburden, the greater will be the cost. Most tunnels located on the Pocahontas mainline have large overburden heights. In general, the costs of daylighting appear higher than those of the other modification methods.

2.5 Cost Estimates

Evaluating the relative costs and methodologies for clearing the many tunnels along the route was a prime engineering objective of this study. NS had developed a preliminary estimate for tunnel clearance costs by applying a unit cost per linear foot derived from a single clearance project at another location. This estimate was not able to consider the characteristics of the individual tunnels, other than length and width, nor did it consider alternative methods for tunnel enlargement.

Absent precise information detailing the track geometry, tunnel geometry, and geotechnical characteristics, it is presently impossible to specify the *best* method (or combination of methods) for enlarging each tunnel. By inspection, however, three of the methods–undercutting, controlled blasting, and scaling–appear to have limited applicability to the Pocahontas mainline tunnels. It is, then possible to estimate the cost, based on previous experience, of applying each of the remaining methods to the tunnels. For current purposes, theefore, modification costs were estimated at each tunnel based on the application of (1) liner removal and crown mining, (2) notching, and (3) daylighting.

Prior to development of the cost estimates, the team collected all existing data on the tunnels. NS provided the length and minimum cross section for each tunnel. A search of company Engineering Department files revealed very little information on the tunnel design or construction. Team members were able to visit each of the tunnels and conduct visual inspections of the portals and lining.

Costing was performed for each tunnel method using unit costs and quantities for each involved operation. These costs were obtained, where possible, from contractors currently performing similar work. The estimates include engineering, exploratory testing, and a five percent contingency fee. Railroad operating costs during construction, the costs of environmental permitting and compliance, and long-term maintenance costs could not be determined at this time. Appendix A provides the methodology employed for estimating the costs for the three procedures evaluated.

Table 2.3 provides the resulting cost estimates for each tunnel. Note that some methods are not applicable to certain tunnels. Thus, the table provides no costs for these methods where they cannot be employed. In general, the cost estimate shows that, for a given tunnel, the known costs of daylighting far exceed those of the other methods.

Table 2.3
Tunnel Modification Costs

	Tunnel Name	*Milepost*	*Liner Removal/*	*Notching*	*Daylighting*	*Notes*
1	Pepper	N 305.4	$11,389,669	$5,441,884	N/A	
2	Eggleston No. 1	N 316.2	N/A	N/A	N/A	Realign to center
3	Eggleston No. 2	N 317.0	$2,512,371	$1,637,878	N/A	
4	Pembroke	N 319.8	$583,760	$288,145	$1,738,133	
5	Cooper	N 374.3	$3,078,317	$1,053,064	$7,788,322	
6	West Vivian	N 392.1	$3,075,166	$1,122,889	$5,118,276	
7	Big Four No. 1	N 394.2	$2,849,517	$1,016,995	$5,686,980	
8	Big Four No. 2	N 395.1	$780,143	$278,688	$631,009	
9	Huger (No. 1 main)	N 395.6	$993,057	$116,454	N/A	
10	Huger (No. 2 main)	N 395.6	$1,259,203	$499,347	N/A	
11	Welch	N 398.9	$5,788,835	$2,048,995	N/A	
12	Hemphill No. 1	N 400.2	$3,871,754	$1,267,657	$5,831,760	
13	Hemphill No. 2	N 400.4	$4,973,067	$1,364,149	$11,702,138	
14	Antler No. 1	N 403.7	$2,671,095	$955,706	$4,181,886	
15	Antler No. 2	N 405.1	$2,727,301	$953,093	$4,080,529	
16	Twin Branch No. 1	N 407.7	$3,292,345	$1,092,696	$6,146,107	
17	Twin Branch No. 2	N 408.1	$3,955,320	$1,400,227	$8,897,175	
18	Vaughn	N 412.1	$4,945,145	$1,704,279	N/A	
19	Roderfield	N 413.1	$3,879,211	$1,105,460	$9,559,781	
20	Laurel	N 414.1	$3,463,048	$1,178,413	$4,023,981	
21	Gordon	N 415.1	$5,925,129	$2,112,911	N/A	
22	Glen Alum	N 439.5	$5,703,090	$2,052,831	N/A	
23	Hatfield (No. 2 main)	N 462.1	$3,787,191	$1,656,798	N/A	
24	Williamson	N 471.6	$2,813,790	$1,128,773	$5,959,880	
25	Big Sandy No. 1	NA 3.3	$9,305,792	$5,365,928	N/A	
26	Big Sandy No. 2	NA 6.0	$1,161,241	$523,139	$1,189,727	Can bypass
27	Big Sandy No. 3	NA 6.8	$6,862,020	$3,347,961	N/A	
28	Big Sandy No. 4	NA 12.7	$6,708,833	$2,545,644	N/A	

The other infrastructure costs, applicable to any scenario, cover clearance modifications to bridges, slide fences, and other overhead structures. Costs for these items were provided by NS and may be found in Table 2.1. The total non-tunnel clearance cost is $2.7 million.

Table 2.4 presents the combined costs of the tunnel and non-tunnel clearance costs. As can be seen, the total costs for notching and liner removal/crown mining scenarios are presented. These may be considered to be, respectively, lower and upper bounds on the overall project cost.

Table 2.4
Summary of Cost Estimates

	N&W Route (Maximum Notching)	*N&W Route (No Notching)*
Tunnel Costs	$43.3 M	$108.4 M
Other Infrastructure Costs	$2.7 M	$2.7 M
Total Costs	$46.0 M	$111.1 M

2.6 Need for Further Assessment

The process used in this report provides a comparative assessment of the costs for tunnel enlargement using different techniques. In general, daylighting is seen to be the most expensive method, with traditional liner removal/crown mining second, and notching the apparent least expensive. Using notching to the maximum extent possible will yield the lowest project capital costs.

The evaluation of the three enlargement methods considers only their capital costs. Each method will also have impacts on train operations, an important issue on the busy Pocahontas mainline. Traffic will experience delays or reroutes due to the construction activity. NS will therefore have increased operating costs during the project. In addition, the need to accommodate train traffic may impact construction schedules, increasing costs for the work. Clearly, these costs may be significant, but they could not be evaluated within the scope of this preliminary analysis. However, notching appears to be far more compatible with train operation than does liner removal/crown mining. This may be an important plus for the method.

On the other hand, if the notching method is to be considered, its performance characteristics need to be assessed in an Appalachian geological setting similar to that of the Pocahontas mainline. Notching has been proven in the very hard rock of the unlined Hoosac Tunnel in Massachusetts. In the western U.S. and Canada, it has been successful in concrete lined tunnels of similar shape and characteristics to those of the Pocahontas mainline. However, the geology of the aforementioned tunnels is very different from that of Appalachia. There is concern that the Appalachian geology, with different rock types and extensive folding and faulting, may result in liner stresses incompatible with the notching process.

Data on the liner materials and thickness, surrounding geologic characteristics, and groundwater hydrology are critical for making decisions regarding the appropriate clearance improvement technique. While little current information exists, there are methods, invasive and non-invasive, for obtaining tunnel data. Invasive exploration requires drilling holes into the tunnel wall to measure liner thickness and sample the materials behind the liner. Drilling from the ground surface is also popular. Non-invasive methods, such as ultrasonic sounding and ground penetrating radar, offer some potential for identifying material types and stratification. None of these tests were possible within the scope of the current study.

Further refinement of the capital cost requires more accurate and detailed data, such as would be derived from a program of geologic testing and field investigation. Drilling from above the tunnels for example, would reveal a great deal more about the geology than is presently known. Core drills through the tunnel liner will reveal the properties of the lining and adjacent rock. The findings will confirm the appropriate clearance method for each tunnel

3.Assessing Project Benefits

3.1 The Nature of Infrastructure Benefits

The placement of a new transportation infrastructure unleashes a wide range of inter-related responses from a variety of users. New infrastructures change relative transportation costs across alternatives and, therefore, often redistribute traffic across the available network. In this way, individuals and business can be affected by the placement of new facilities hundreds or even thousands of miles away.

As traffic shifts in response to changes in relative transportation costs some users will likely be made better off, while other users may be harmed. From an economic perspective, the hope is that the gains to those made better are sufficient so that they would be able to compensate those who are harmed.[22] This is equivalent to suggesting that *net* benefits exceed *net* costs. Accordingly, any project with a benefit-cost ratio that exceeds one is judged as economically efficient.

Net benefits or actual efficiency gains are distinguishable from simple economic transfers that relocate economic activity from one set of economic agents to another with no net increase in economic welfare. While zero-sum transfers have very real impacts on the involved parties, they cannot justify policies or projects on a system-wide basis.

In reality, most transportation projects generate both real efficiency gains and economic transfers. Thus, when assessing the probable economic impacts of a proposed project, analysts must carefully segregate benefits into the appropriate category. In the current setting, as in nearly every case, this task is quite challenging.

In the search for legitimate project benefits, there are several potential sources that must be investigated. If the proposed project generates real efficiency gains, these gains are likely to accrue in a number of different places. First, to the extent that there are transportation savings on existing traffic and Norfolk Southern can retain these savings, the gains may appear as increased firm profits. However, to the extent that there is effective competition in intermodal markets, project-related cost reduction may well translate into lower transportation rates for existing users. In such cases it is the shippers (and their customers) who actually benefit.

As relative transportation costs (and presumably prices) change, it is very possible that the improved route will not only see usage by existing NS intermodal traffic, but that new traffic will be added to the routing from two important sources. First, as relative transport costs on the NS routing fall, it is

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[22] If this condition is met, the infrastructure is said to represent a *Pareto* improvement. In practice, even though winners are able (and should be willing) to compensate losers, they are seldom asked to do so.

likely that traffic will be diverted from other competing routes – either all-truck routes or competing rail routings. In such cases, the efficiency gain is appropriately measured as the difference between the transportation cost on Norfolk Southern and the cost of transportation prior to the diversion.

The second source of incremental new traffic relates to the general role of transportation as an input to production. As shippers gain transportation-related savings, they become more competitive in comparison to alternative goods and services. Accordingly, they are able to sell increased volumes of output. This means that, based on increased competitiveness, these shippers will need more of every productive input – including transportation services.

The discussion, thus far, has focussed on pure transportation-related savings. In reality, project benefits include efficiency gains in any component of the supply chain. The proposed improvement will lead to transportation cost savings, but it will also reduce transit times by as much as fifty percent. Because one party or another must finance inventories while they are in transit, the reduced transit times represent reduced finance charges. Any such inventory savings are just as important as reductions in fuel, crew, and equipment costs.

Finally, as traffic is reallocated, the proposed project may affect the cost of moving products on other segments of the transport network. Specifically, the project has the potential to reduce costs by reducing congestion as traffic is diverted or reduced volumes may increase unit costs by limiting the capture of scale economies. In some settings the network effects can play a prominent role in redefining the magnitude of project benefits.

3.2 Benefits to Existing Users

As noted, existing users will likely benefit from the proposed clearance project in two ways. First, the competitive process will likely translate reduced transportation costs into lower rail rates for container movements. Second, reduced transit times will lead to lower inventory holding costs.

Current NS routings from Norfolk to Columbus Ohio, as well, as the West Virginia routing, are depicted in Figure 3.1. All NS routings between Norfolk and most mid-western locations are similarly circuitous. Representative transit distances are provided in Table 3.1

Depending on routing and origin-destination pair, the route via West Virginia is between 120 and 371 miles shorter than the current double-stack cleared NS routes. This represents a reduction in distance of 10 percent – 36 percent. Every cost that is traffic-sensitive would be reduced by that amount and every such cost reduction would represent an efficiency gain attributable to the proposed project.

Figure 3.1
NS Routes Between Norfolk, VA and Columbus, OH

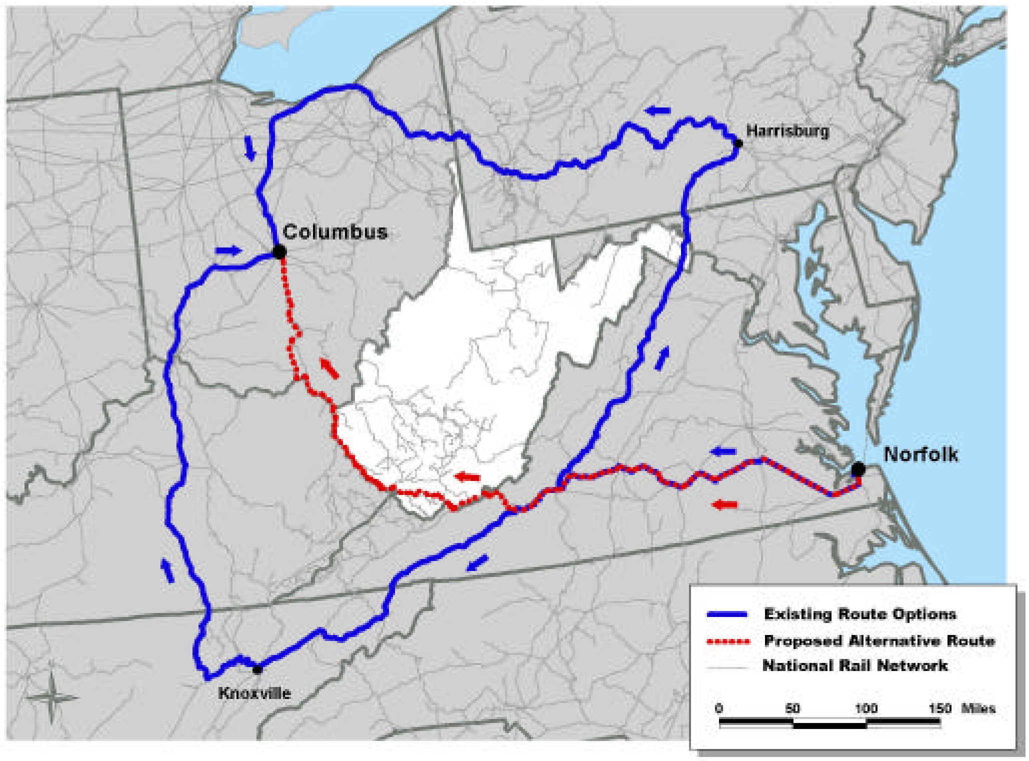

Table 3.1
Representative NS Transit Distances

(Parentheses Indicate Distance Savings via West Virginia)

To	*From Norfolk via Knoxville*	*From Norfolk via Harrisburg*	*From Norfolk via West Virginia*
Chicago	1,169 **(-120)**	1,251 **(-202)**	1,049
Detroit	1,164 **(-289)**	1,078 **(-203)**	875
Columbus	967 **(-300)**	1,038 **(-371)**	667

Savings attainable through the re-routing of double-stack trains via West Virginia can be summarized as

$$\sum_{i=1}^{n} C_i TM$$

where:

Ci = a distance sensitive cost item
TM = the effected volume of traffic measured in ton-miles.

Currently, NS does not use the Knoxville routing for most double-stack trains, choosing instead to route traffic via Harrisburg.[23] Nonetheless, in an effort to produce conservative estimates, the study team opted to use the shorter routing distances and smaller distance savings in calculating the effected ton-miles. The effected number of tons was developed from NS-supplied data on lane-specific traffic volumes. Traffic volumes were reduced to reflect the fact that NS operates one single-stack container train daily in each direction between Norfolk and Chicago via a West Virginia routing. NS provided the number of containers. The study team, then used data from the Surface Transportation Board's (STB) Carload Waybill Sample to estimate tons per container

The cost parameters were developed through use of the STB's annual R-1 reports. NS-specific data were converted to a ton-mile basis. Only traffic sensitive cost items were included within the benefit calculation. For example, crew, fuel, and equipment costs all increase with an increase in ton-miles. However, the cost of maintaining signal systems does not generally vary with train traffic. Where necessary, engineering judgement was used to adjust the R-1 data to reflect the intermodal focus (i.e., greater fuel usage, smaller crew costs). A full set of cost parameters is provided in Appendix B. These parameter values are summarized in Table 3.2

For estimation purposes, the study team assumed a nominal cost of capital of eight percent, implying that the real cost of capital is approximately five percent. This parameter value was confirmed with transportation cost specialists at the Tennessee Valley Authority (Knoxville, Tennessee).

Because the expected asset life for the right-of-way improvements is 20 years, it was necessary to estimate the growth rate of container traffic over the same time horizon. As indicated, intermodal traffic has grown rapidly over the past decade. The question, of course, is whether or not this growth will continue and, ultimately, how variations in traffic growth affect the efficiency of the proposed project. In order to accommodate these questions, the analysis used

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[23] The Harrisburg routing allows Norfolk traffic to be combined with traffic from northeastern origins and for westbound movements. Eastbound traffic is split at Harrisburg.

Table 3.2
Summary of Cost Parameters

CAPITAL COSTS	Per Revenue Ton-Mile
Way and Structure	0.00102
Equipment	0.00112
Total Capital Cost	**0.00214**

OPERATING COSTS	Per Revenue Ton-Mile
Way and Structure	0.00307
Locomotive Maintenance	0.00438
Freight Car Maintenance	0.00598
Other Equipment Costs	0.00103
Transportation Costs	0.01059
Other Costs	0.00013
Total Operating Costs	**0.02518**

TOTAL	Per Revenue Ton-Mile
Capital + Operating Cost	**0.02732**

three separate growth rates to produce a range of benefit values. The mean annual growth in container movements over US ports for the 1990 – 2000 period was 6.5 percent. The standard deviation was 2.0 percent. Therefore, benefits for double stack traffic moving over the cleared routing were calculated using growth rates of 4.5 percent, 6.5 percent, and 8.5 percent.

In addition to reductions in transportation costs, the proposed project would significantly reduce the transit times of double-stack movements currently using the circuitous routes. Estimating the benefits associated with these reductions required a number of assumptions. First, based on representations by Norfolk Southern, the study team assumed that the direct route would reduce transit times by 36 hours. Next, container contents were valued at an average of \$1.49 per pound.[24] Finally, the study team assumed a real short-term interest rate of 6.125 percent. These parameters were combined with the forecast of current and future traffic volumes to produce the appropriate benefit estimates.

Not all container traffic between Norfolk and the mid-west uses the circuitous Knoxville or Harrisburg routings. As noted, NS operates one single-

[24] The value per ton was estimated based on 1999 traffic over the port of Norfolk.

stack train between Norfolk and Chicago in each direction each day. These single-stack shipments would immediately shift to a double-stack configuration.

The parameters summarized in Table 3.2 reflect the estimated cost of double-stack movements. Single-stack shipping is far more expensive. The probable savings to current single-stack shippers also constitute a benefit attributable to the proposed project.

To determine the magnitude of these efficiency gains, it was necessary to develop an estimate of single-stack shipping costs. Estimates of the single-stack / double-stack cost differential range between 1.33 and 1.85, depending on assumptions regarding train length, trailing tonnage restrictions, etc. For the purpose of the current analysis, a mean value of 1.59 was used to reflect this differential.

A year-by-year tally of expected traffic and project benefits to current users under a variety of scenarios is provided in Appendix C. These results are summarized in Table 3.3. The three scenarios depicted in this table involve diverting various quantities of traffic from current routings to a West Virginia route over a 20-year period. Present values were calculated based on a real discount rate of 6.125. This relatively high rate is intended to capture the risk that out-year benefits may never be realized.

Table 3.3
Estimated Project Benefits from Existing and New West Virginia Users

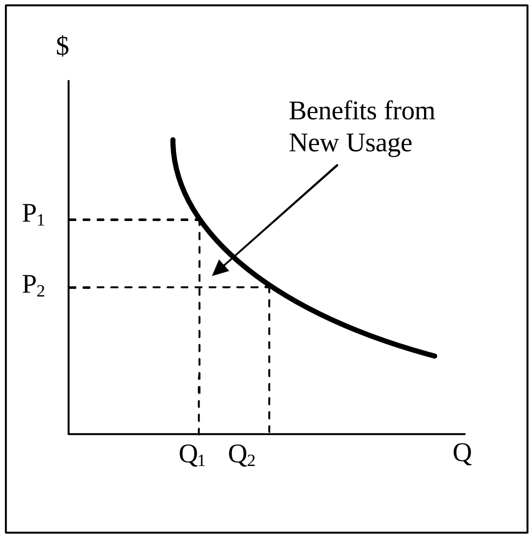
(Present Value over a 20 year time horizon. Discount Rate = 6.125%)

Traffic Base	*4.5% Annual Growth in Intermodal Traffic*	*6.5% Annual Growth in Intermodal Traffic*	*8.5% Annual Growth in Intermodal Traffic*
Norfolk – Columbus, Norfolk – Chicago	$201 million	$239 million	$288 million
Norfolk – Columbus, Norfolk – Chicago, Norfolk – Detroit	$216 million	$258 million	$311 million
Norfolk – Columbus, Norfolk – Chicago, Norfolk – Detroit, plus West Virginia Traffic	$256 million	$305 million	$368 million

3.3 New Usage

Figure 3.2 shows a hypothetical demand curve for some transportation service. Assuming a project-related reduction in price from P_1 to P_2, current users would save an amount equal to the area of $(P_1 - P_2)Q_1$. However, the transacted quantity of service would not remain at Q_1. Instead it would increase to Q_2. The increased traffic volume might represent additional usage by current customers or it could be the result of traffic diversions; the source matters little. What is clear is that this additional usage generates additional project benefits. In the example, assuming constant marginal costs, the value of these benefits is represented by the area between.Q_1 and Q_2 below the demand curve and above P_2.

Figure 3.2
Hypothetical Demand Setting



Estimating the benefits associated with increased usage requires data describing the probable responses of current users to changes in intermodal rates. These data are not readily available and, moreover, estimating the demand characteristics of intermodal users is well beyond the scope of the current study effort.

It is possible, however, to use previous research to judge the extent to which fully capturing these additional benefits might affect the overall study conclusions. Burton (1999) estimated the short-run own-price demand elasticities for the railroad movement of individual and aggregated bulk commodities. The parameter estimates ranged between –0.34 and –0.99.[25] These estimates are generally consistent with the value of similar elasticities estimated elsewhere. Given these values and considering that corresponding long-run demand relationships are bound to be more responsive, it is not unreasonable to assume a value of unity. Under such an assumption, and presuming that the demand relationship is convex (as it should be in a spatial setting), the difference between Q_1 and Q_2 is approximately 10,000 units in the first year of the analysis.

[25] See, "Calculating the Value of Upper-Mississippi River Navigation: Methodological Review and Recommendations," US Army Corps of Engineers, Rock Island District, 1999.

Thus, any error associated with omitting the subject benefits is likely less than 10 percent.

3.4 Network Effects

Network production technologies yield complex interdependencies that do not exist in most other economic settings. Specifically, the disposition of one shipment can positively or negatively impact the cost of providing another shipment on a different portion of the network.

In the present investigation, diverting intermodal traffic from its current routes to a West Virginia routing could *potentially* impact the cost of moving intermodal shipments between other east-coast ports and the mid-west. Similarly, it could alter the cost of transporting the coal that is currently moving over the carrier's West Virginia trackage. To the extent that these network effects further reduce transportation costs, they should be counted as additional project benefits. Alternatively, to the extent that network effects make other commodity movements more costly, project benefits should be reduced.

To test for network effects, the study team used *RAILNET* to simulate NS system-wide operations under conditions where the West Virginia route is cleared for double-stack container movements.

Given a matrix of commodity flow demands between origin and destination pairs, *RAILNET* will predict the likely volume of flow on each link in a rail network. The GIS-based software relies on a multi-commodity equilibrium assignment algorithm to distribute traffic over applicable network segments so that total system costs (shipper and carrier) are minimized. The model formulation is capable of reflecting:

- The flow of multiple separate commodity classes, each having a distinct pricing structure;
- The network topology of the modeled transportation system, including line haul arcs, terminals, and transfer points;
- Corporate ownership of network elements;
- Service characteristics of various network elements, such as line haul links and terminals; and
- Restrictions on the movement of commodities over specific carriers or network elements as needed to reflect operational practice.

The flow patterns generated by *RAILNET* accurately reflect the underlying decision logic used by shippers and railroad managers in routing traffic. Given a flow volume and a service function for each facility, the average travel time, and thus delay, can be calculated for that facility. Facilities having an excessive amount of delay can be targeted for additional study using more detailed modeling approaches such as simulation.

The *RAILNET* analysis suggested that given current commodity flows, the diversion of existing (and foreseeable) intermodal traffic to a West Virginia routing would not materially affect the shipping cost of other NS movements. The only conditions under which costs change significantly involve a substantial growth in coal traffic that seems unlikely at the current time.[26]

3.5 Regional Economic Benefits

As noted above, efficiency gains rather than regional economic development benefits are generally used to justify federal participation in the funding of transportation projects. The current analysis does not deviate from this practice. Nonetheless, the proposed project would remove a substantial barrier that currently makes it difficult for West Virginia firms to engage in international commerce.

The intermodal initiative, as currently envisioned, includes a mechanized intermodal facility within the study region – possibly at a site near Prichard, West Vrginia. The incremental costs to NS of serving such a facility would be modest, but the affordable intermodal access it could provide to regional shippers has the potential to be of great value.

The RTI study team used economic and demographic data in combination with NS traffic data to estimate a statistical model that predicts site-specific inbound and outbound container volumes. The final model may be represented as:[27]

$$\begin{aligned} \text{NUMUNIT}_i = \beta_0 + \beta_1(\text{HALF}_i) + \beta_2(\text{CSXO}_i) + \\ \beta_3(\text{OPOP}_i) + \beta_4(\text{CSXD}_i) + \beta_5(\text{DIST}_i) + \beta_6(\text{RUM}_i) + \\ \beta_7(\text{OPORT}_i) + \beta_8(\text{WGATEO}_i) + \varepsilon_i \end{aligned}$$

where:

NUMUNIT_i = the number of containers
HALF_i = a dummy variable indicating that the record is for the first half of the year.
CSXO_i = a dummy variable indicating whether or not the origin also had CSX intermodal service
OPOP_I = population at shipment origin

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[26] The US Department of Energy's Energy Information Administration predicts a modest decline in West Virginia coal production over the coming two decades See *Annual Energy Outlook: 2002.*

[27] The actual model also contained a number of quadratic and interaction terms.

$CSXD_I$ = a dummy variable indicating whether or not destination also has CSX intermodal service
$DIST_I$ = the rail shipping distance
RUM_I = the average unit revenue
$OPORT_i$ = a dummy variable indicating whether or not the origin city is a seaport
$WGATEO_I$ = a dummy variable indicating whether or not the origin city is a gateway with a western railroad

The NS data that supported parameter estimates is both proprietary and competitively sensitive, so that it is not appropriate to include these parameter estimates in study documents. However, estimated traffic flows over a West Virginia facility based on these parameters are presented in Table 3.4.[28]

Table 3.4
Estimated First-Year West Virginia Container Traffic

	To	*From*	*Total*
Norfolk	3,416	2,294	5,710
Chicago	2,412	714	3,126
Detroit	438	2,352	2,790
TOTAL	6,266	5,360	11,626

Based on a five-day per week schedule, these estimates translate into roughly 45 total (inbound and outbound) containers each day. The overall magnitude of these estimates squares with anecdotal estimates provided by NS officials as a reasonable expectation for a first-year operation. However, The design capacity for the terminal as currently envisioned is 30,000 containers per year, so that it could easily accommodate any traffic growth that might result from promotional activities.

Figures representing the maximum potential economic value to regional shippers of the proposed facility are reported in Table 3.5.[29] These values were produced by using the first year figures and maximum terminal capacity as lower

[28] For estimation purposes, the relevant service area consisted of the Huntington and Charleston Metropolitan Statistical Areas (MSA's).

[29] Given that it is impossible to verify shipper savings on movements that do not actually occur in the current environment, these estimates merely reflect the magnitude of potential benefits. Actual values are unknowable.

and upper traffic bounds, and by assuming that the availability of the facility can lower overall container costs by $376.[30]

Again, it must be emphasized that the vast majority of these values likely represents a transfer of economic activity from an alternative production location. Still, for western West Virginia, southern Ohio, and eastern Kentucky, the economic influence of improved access to intermodal transportation could be pronounced.

Table 3.5
Potential Regional Economic Values
(in millions)

	Lower Bound	*Upper Bound*
Annual Savings	$4.4	$11.3
Present Value	$49.6	$82.7

Given these values and recognizing that transportation, on average, represents 13 percent of economic activity, it is not unreasonable to assume that the availability of affordable rail / truck intermodal transportation could generate new regional economic activity well in excess of $50 million each year. This, in turn, would likely mean hundreds of new jobs.[31]

3.6 Uncounted Project Benefits

There are invariably project benefits which are left uncounted only because they are difficult to measure in a defensible way. This is certainly true in the current setting.

First, rail transportation is roughly four times more fuel-efficient than motor carriage. Thus, to the extent that the proposed project diverts highway traffic to truck / rail routings, it could measurably reduce fuel consumption and pollutant emissions. These outcomes represent tangible project benefits that remain uncounted in the current setting.

[30] The 1999 RTI study cited above estimates that Huntington area shippers pay a $438 dollar drayage charge between Columbus and the Tri-State region, while Charleston shippers pay $515 for the same service. The value used here is the average of these figures minus the $100 fee that is typical for a local dray. Maximum terminal capacity was attained by increasing first year traffic estimates on an annual basis at a rate of 6.5 percent until traffic volumes reached 30,000 containers per year.

[31] Based on state-wide labor productivity in manufacturing, $50 million in additional output would equate to 350 manufacturing sector jobs.

There is a more subtle argument that appears in a recent study proffered by the American Association of State Highway Transportation Officials (AASHTO).[32] The report suggests that public infrastructure investments are inevitable and that the magnitude of these investments will be much greater if they are focussed entirely on motor carriage. Thus, the report concludes that any difference between an all-truck investment scenario and a rail-inclusive pattern of public investments should be viewed as a benefit to using rail.

[32] See *Transportation: Invest in America Freight-Rail Bottom Line Report*, American Association of State Highway Transportation Officials, January 2003. This same AASHTO report (p. 102) describes the proposed double-stack clearance project as one of three multi-state rail corridor projects with a potential to provide significant public benefits.

4.Project Financial Structure

4.1 Efficient Project Funding

From an efficiency standpoint, the marginal contribution of each funding party should equal that party's marginal gain. This suggests that the various affected constituents should bear a financial responsibility that is equal to the benefits they receive from the proposed project.

In the current setting, however, the sum of all predicted benefits is greater than the sum of anticipated costs. Accordingly, the analysis proceeds under the assumption that financial participation should be *proportional* to anticipated benefits.[33] This concept can be summarized mathematically as:

$$\text{Project Cost} = \sum_{i=1}^{n} l \; B_i$$

where:

B_i = the benefit accruing to the i^{th} constant
? = a scalar with a value between zero and one.[34]

In the current setting, there are, at least three identifiable sources of project benefits. These include any incremental profits captured by Norfolk Southern, the development benefits captured by residents of the areas that see increased economic activity, and the savings to customers of shippers who are likely to benefit from reduced transportation costs and transit times. Each group should expect to contribute to project funding in an amount that is, at least, roughly proportional to these benefits.

4.2 Norfolk Southern Profitability

Section 3 provides estimates of overall project-related efficiency gains. However, if the analysis is to efficiently apportion financial responsibility for the proposed project, it is also necessary to estimate the proportion of cost savings that Norfolk Southern might be able to retain as incremental profits.

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[33] Economic theory does not require this proportionality, only that funding be divided so that all parties are made better off by the project than they would be in its absence.

[34] True economic efficiency suggests that benefits should precisely equal costs. However, in a setting where investments are "lumpy", this may not always be possible, so that the scalar may take on a value of less than one.

In an environment entirely devoid of competition, a reduction in incremental cost would likely lead to a small price reduction and a modest increase in traffic. Most cost savings would be retained as additional firm profits. Alternatively, to the extent that markets for the subject services are effectively competitive, the vast majority of transportation savings would be expected to pass through to shippers. Ideally, the determination of the degree of competitiveness would rest on precise, verifiable information describing Norfolk Southern's price-cost margins on intermodal traffic. However, this information is incredibly sensitive and was, therefore, unavailable. Fortunately, there are alternative tools for assessing competitiveness in the relevant intermodal markets, so that it is possible to make defensible inferences.

The study estimates that roughly 25 percent of the affected traffic currently moves in a single-stack configuration. The primary competition for this traffic is motor carriage. Indeed, nearly one-third of all container traffic between east coast ports and the mid-west moves by truck.[35]

The balance of the subject traffic moves in a double-stack configuration. The cost advantage provided by double-stacking is likely sufficient to render motor carriage ineffective as a means of competition. Thus, the question becomes whether or not there exists an adequate number of non-NS rail / truck alternatives to provide pricing discipline.

Norfolk Southern's primary rail rival in the relevant markets is CSX Transportation. CSX serves each of the mid-west markets that would be effected by NS clearance project and it also has a small presence at Portsmouth, so that there is a competitive presence in the specific traffic lanes that would be by the proposed project. More importantly, however, the Port of Norfolk competes with a variety of CSX-served east coast ports. For example, the CSX presence at the Port of Charleston (SC) easily rivals NS operations at Norfolk and both CSX and NS operate multiple facilities in the New York / New Jersey port area. Finally, while CSX is Norfolk Southern's chief rival, the Canadian carriers (Canadian National and Canadian Pacific) also supply a competitive influence. In particular, the Canadian National routing between Halifax and the upper mid-west is very attractive to shippers.[36]

Finally, the study team considered the fact that NS has not made the required infrastructure improvements independent of any public–private partnership. The potential savings are well known to the carrier, as are the modification costs. Thus, if the project currently under study was capable of yielding a substantial level of profits, it should have been undertaken privately long ago.

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[35] See, *Great Lakes and St. Lawrence Seaway Potential Container Transportation Savings Analysis*, US Army Corps of Engineers, Huntington District, 2002.

[36] Because of its deep draft, Halifax is often the first port of call for ships from Europe and the last port of call for ships bound for Europe. Consequently, even though the rail distance to US destination is greater than the rail distance from US ports, transit times can actually be less.

Ultimately, the study team elected to assume that the proposed project would yield pre-tax profits of between seven and 13 percent.[37] This value, combined with estimated cost savings, yields an expected present profit value of between $21 and $40 million over a 20 year time horizon under a 6.5 percent rate of traffic growth. However, recalling that project benefits exceed project costs by a factor as large as six, the appropriate NS share would be only a fraction of the gain in profits.

There are a number of mechanisms for recovering Norfolk Southern's share of project costs. For example, the carrier may make an in-kind contribution of real property for a West Virginia intermodal facility. Alternatively, funds may be collected on a per-carload basis as the improved right-of-way is used. Finally, NS may be asked to provide cash at the project's outset. From an economic perspective, there is no real advantage to these (or other) funding alternatives.

4.3 National Network Efficiency Gains

The transportation and inventory cost reductions described in Section 3 represent real efficiency gains. Other than the small incremental addition to Norfolk Southern profits, these efficiency gains will accrue to the general public throughout much of the United States. As transportation costs fall, competition between transport alternatives will cause rail / truck rates for intermodal services to fall.[38] Further competition assures that shippers will pass the majority of rate savings to their customers in the form of lower prices. Ultimately, it is final consumers who would receive the benefits of the project-induced efficiency gains. Because the majority of the estimated benefits would accrue to the public, it is appropriate for federal sources to fund the majority of project costs.

4.4 Reflecting Regional Benefits

As noted, the economic efficiency of an overall project is largely unrelated to the magnitude of regional economic development benefits. Thus, historically, regional jurisdictions have not always been asked to participate in the financing of transportation projects that yield efficiency gains, particularly when these gains are likely to accrue outside the jurisdiction where the

[37] Thirteen percent represents a 10-year average of the ratio of Net Income to Revenue – the accounting analogue to "economic" profits. In the case of NS this value varied greatly over this period (2.7% - 18.8%) because of the influence of the Conrail transaction on financial performance. The lower bound of seven percent reflects the industry-wide difference between overall firm profits and profits on intermodal traffic.

[38] This is precisely the process that lead to lower rail rates in the wake of the cost cuts associated with the 1980 Staggers Rail Act. See, Mark L. Burton, "Railroad Deregulation, Carrier Behavior, and Shipper Response: A Disaggregated Analysis," *Journal of Regulatory Economics*, December, 1993.

infrastructure is placed.[39] When federal programs do require local or state matching funds, the match requirement is generally confined to 10% - 20%.

In this light, it is not entirely clear that the states of West Virginia, Ohio, and Kentucky should be required to contribute funds to the proposed project. On the other hand, given the tremendous potential economic benefits to the region, these states should be more than willing to participate financially if the situation requires it.

Cost estimates for achieving the required clearances range between $43 million and $111 million. A West Virginia intermodal facility and associated highway access is expected to cost an additional $16 million so that required funds range between $59 million and $127 million. Based on the discussion in this section, Table 4.1 provides a potential division of required funding that includes state participation.

Table 4.1
Potential Financial Participation (I)

(Values in Millions)	*Low Cost Scenario*	*High Cost Scenario*
Total Costs	$59.3	$127.1
Federal Share	$47.4	$101.1
State(s) Share	$5.9	$12.7
NS Share	$5.9	$12.7

Alternatively, given that NS would not opt to build a regional intermodal facility outside the context of the overall project, it may be more desirable to remove the states from the clearance funding formula, but make them solely responsible for financing the intermodal facility. Cost shares under this latter scenario are reported in Table 4.2

Table 4.2
Potential Financial Participation (II)

(Values in Millions)	*Low Cost Scenario*	*High Cost Scenario*
Total Costs	$43.3	$111.1
Federal Share	$39.0	$100.0
State(s) Share	----	----
NS Share	$4.3	$11.1

[39] For example, the US Army Corps of Engineers does not require states to participate in the funding of navigation structures, even though these structures have measurable regional economic impacts.

5. *Conclusions and Study Recommendations*

In the Twentieth Century, the United States developed an unprecedented freight transportation system. The nation's rail network was completed. Motor carriage emerged and a breathtakingly extensive highway network was created to accommodate this new mode. Navigation locks were built and inland barge transportation matured as a handler of bulk commodity shipments.

With some rare exceptions, the basic skeleton of the US transportation network is complete. There are very few opportunities to enhance the efficiency of this system by adding new route segments. At the same time, the demand for additional transportation capacity continues to grow without abatement. If this incremental demand is to be met, the Twenty-First Century must be an era in which transportation planners and policy-makers identify and pursue methods for increasing the productivity of the system that is already in place. New capacity must come through improved operational efficiency, not just through new construction.

The current analysis has its roots in a study designed to identify transportation challenges and potential remedies in western West Virginia. The estimated regional impacts of the proposed intermodal project suggest that this initial goal would be well served by this effort. Almost inadvertently, however, the proposed initiative goes much further by providing potential benefits that are national in scope.

Certainly western West Virginia, southern Ohio, and eastern Kentucky would benefit from the availability of affordably priced truck / rail intermodal service. Just as clearly, however, the infrastructure improvements that could foster these regional advantages would also yield improved levels of national intermodal network efficiency.

The initial beneficiaries of the proposed project would be the mid-Atlantic and mid-western shippers (and their customers) who, through the process of competition, could expect to see reduced transportation costs translated into lower freight rates and delivered product prices. The elimination of circuitous routes and reduction in single-stack movements will generate millions of dollars worth of savings. These benefits may be expected independent of any impacts the project may have on commerce in the central Ohio River basin.

This realization does not, however, mean that the regional development impacts on western West Virginia, southern Ohio and eastern Kentucky should be trivialized. To the contrary, the availability of affordably priced intermodal service will open a gateway to international commerce that does not currently exist. Even conservative estimates suggest that an in-region intermodal facility would see traffic volumes reflective of millions of dollars in new economic activity and hundreds of additional jobs.

The infrastructure improvements that could bring about these changes cannot be accomplished unilaterally by any of the concerned constituencies. Class I railroads are private sector concerns with responsibilities to shareholders. Accordingly, so long as the return on the investment needed to attain greater tunnel clearances is lower than the returns achievable through competing capital projects, Norfolk Southern will not make this investment. Without the ability to move containers in a double-stack configuration, West Virginia and its regional neighbors can do nothing to remedy a transportation barrier that is effectively isolating the area from many international markets. Absent the public-private partnership that has sustained the investigation to this point, no project will be possible and no benefits will be realized.

If the necessary clearances are achieved, shippers and their customers will save an estimated $13.1 million during the first full year of operation. This value takes into account the fact that NS is expected to retain 13 percent of transportation savings as incremental additions to firm profits. As traffic grows, these savings will grow, so that in the twentieth year of operations, the cleared route may be expected to yield over $45 million in (real dollar) shipper savings. Unfortunately, none of these savings are achievable until the very last clearance restriction is mitigated. Thus, the ability to capture the maximum possible value from the proposed project depends greatly on the speed with which this effort can move forward.

Based on this realization, the study team offers the following recommendations:

- Steering Committee members should review the current study outcomes with their respective organizations and work to identify any available funds that might be used to perform the preliminary engineering tasks identified in Section 2.

- The current project Steering Committee should explore the processes for forming a multi-state compact and other necessary formal relationships necessary to the further pursuit of this project.

- Designees of the Steering Committee should meet with federal Congressional leaders from Kentucky, Ohio, Virginia, and West Virginia to familiarize the members with the current process and to seek Congressional support.

- The current study's Principal Investigators should continue to refine estimates of benefits and costs, so that the decision making process is as well informed as possible.

Appendix A

COSTING METHODOLOGY

The following sections discuss the approach used in the development of each item in the engineering estimates.

A-11 Liner Removal and Crown Mining

Cost estimates for the liner removal method are based on the procedure employed for the 1990 NS Montgomery tunnel enlargement in Virginia. This tunnel enlargement project included geologic investigation, grouting, liner removal, roof excavation, rock bolting and shotcreting. Each of these steps is considered in estimates of the cost of liner removal and crown mining for the Pocahontas mainline tunnels.

As a part of the geologic investigation, test holes are drilled from the ground surface toward the tunnel crown. For a given tunnel, drilling costs will be based on the number and depth of boreholes. Cost estimates for drilling are based upon the following assumptions:

- Ground slopes at both tunnel portals were considered equal and linear.
- The maximum depth of overburden for a tunnel is the difference between the average tunnel elevation and the highest ground contour over the tunnel.
- The top of the mountain or crest is assumed to be flat.
- It was assumed there would be a horizontal distance of 75 feet between boreholes.
- The number of bores = $\frac{\text{tunnel length}}{75\ \text{ft}}$
- The depth of each bore was calculated by taking the respective horizontal distance and multiplying this distance by the slope of the mountain.

Before the roof lining is removed, grout is injected as necessary to strengthen the surrounding rock mass and reduce groundwater flow. This estimate assumes grout injection behind the complete area of the lining. The grout volume required for a tunnel is calculated using the following equations:

$$V_v = \frac{e}{1 + e} V_t$$

where:

e = porosity;
V_t = total volume; and
V_v = void (grout) volume.

Then

$$V_t = (A)(d) = (pr^2)(d)$$

where:

> *A* = area of grout penetration;
> *d* = depth of grout penetration; and
> *r* = radius of grout penetration.

The estimate assumed the following values for parameters:

> Porosity, *e* = 0.3;
> Grout penetration radius, *r* = 2.5 ft;
> Grout penetration depth, *d* = 1 ft; and
> Tunnel radius = 7 ft.

The number of grout injection points for a tunnel is based on the liner area and the effective coverage area of an injection point:

$$\text{num grout holes} = \frac{\text{tunnel liner cicumferen ce} \times \text{tunnel length}}{p\ 2.5^2}.$$

The cost of roof excavation is roughly proportional to the total volume of material removed. The estimate assumed excavation of the tunnel roof to a nine feet radius centered on a point on the track centerline 15 feet above the existing top of rail. In double track tunnels, the roof portion between tracks was cleared to the full 24 foot height above top of rail. For each tunnel, the excavated cross section was plotted to scale on the existing tunnel cross-section. Measurement of the removed area was done using a planimeter. The volume of removed material is the product of this area and the tunnel length. The estimated volume includes the old liner and any additional rock to provide the desired cross-section.

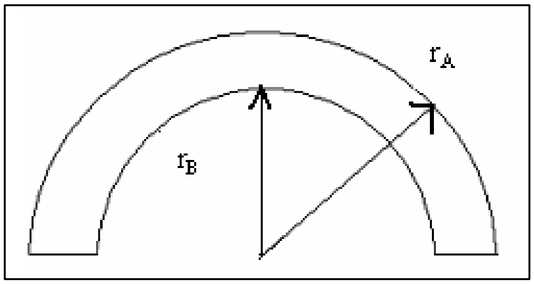
Rock bolt placement is estimated based on the experience at Montgomery Tunnel. Each free standing tunnel sidewall is tied to the surrounding rock mass by a row of rock bolts along the top edge at five foot intervals through the length of the tunnel. In addition, rock bolts are installed every five feet around the circumference of the excavated roof, with the pattern repeating at five feet increments along the tunnel length.

The estimate for liner replacement is based on shotcrete application. The cost is assumed proportional to the volume of shotcrete required. The cross-sectional area of shotcrete is determined using a one foot thickness, as follows:

$$\text{Area of shotcrete} = \frac{p\,(\mathrm{r_A})^2 - p\,(\mathrm{r_B})^2}{2}\ \mathrm{ft}^2$$

where r_A = 9 ft and r_B = 8 ft, as illustrated in Figure #.1.

Figure A.1
Shotcrete Volume Estimation



To obtain a volume in cubic yards, the area is multiplied by the tunnel length and divided by 27.

Tables A.1 and A.2 provide, respectively, unit costs and an example based on Cooper Tunnel.

<u>Tunnel Notching Costs</u> Compared with crown mining, tunnel notching is a relatively straightforward process, especially when the tunnel requires relatively shallow cuts to provide double stack clearance. Many of the tunnels on the Pocahontas mainline fall into this category. However, if notching penetrates the tunnel liner, additional work may be required to ensure stability. Since lining thicknesses for the Pocahontas tunnels are not known for certain, conservative assumptions will be made in the estimates.

The first assumption is that each notched tunnel will be fully grouted using methods described under the liner removal and crown mining. In reality, most notched tunnels do not need grout unless the notch is sufficiently thick to weaken the lining.

It is assumed that, in cases where the notch depth exceeds six inches, two ten-foot rock bolts would be placed adjacent to the notch every five feet through the length of the tunnel. These rock bolts would secure the liner to the surrounding rock mass.

The cost estimates are based on notches providing a clearance of 21 feet above top of rail over a 5-½ ft width from the track centerline. At most two notches would be required for a tunnel. The current costs for tunnel notching were obtained from contractors who specialize in this type of work.

Table A.1
Final Unit Costs

Description	*Unit Cost*	*Source*
Mobilization/Demobilization	10% of Total	Assumed
Engineering Costs	10% of Total	Assumed
Field Engineer	$1,000/ day	Contractor
Clearance Excavation	$350 /yd^3	Assumed
Ten-Foot Long Rock Bolts	$500 /Bolt	Contractor
Shotcrete with a Thickness of 12 Inches	$650 / yd^3	Contractor
Grout	$142 / yd^3	RS Means
Grout Hole	$10 /Hole	RS Means
Rock Boring	$54 /Linear Foot	RS Means
Production Rate	10 ft/hr	Assumed
Track Time	5 hrs/ day	Contractor
Mobilization/Demobilization	2 days	Assumed

Table A.2
Sample Liner Removal/Crown Mining Costs–Cooper Tunnel

Item	*Quantity*	*Unit*	*Description*	*Unit Cost*	*Total*
1	1	Lump Sum	Mobilization/Demobilization	$244,311	$244,311
2	1	Lump Sum	Engineering Costs	$244,311	$244,311
3	7	Days	Exploratory Work	$2,500	$17,500
4	46	Days	Field Engineer	$1,000	$46,000
5	2043	Cubic Yard	Clearance Excavation	$350	$714,985
6	1256	Each	Ten-Foot Long Rock Bolts For Roof	$500	$628,200
7	140	Each	Right Rock Bolt	$500	$69,800
8	140	Each	Left Rock Bolt	$500	$69,800
9	1026	Cubic Yard	Shotcrete with a Thickness of Twelve (12) Inches	$650	$666,939
10	1135	Cubic Yard	Grout	$142	$161,145
11	977	Each	Grout Hole	$10	$9,772
12	1092	Linear Feet	Rock Boring	$54	$58,968
13	1	Lump Sum	Contingency (5%)		$146,587
TOTAL COST FOR ENLARGEMENT					**$3,078,317**

The notching method requires exploratory work that averages $2,500 per day. This cost includes drilling truck, crew, drilling equipment, and living expenses.

The grinder's production rate in concrete is approximately 25-35 ft/hour, with material depth of 12 inches. Track time for grinding is assumed to be a conservative five hours per day. The following formula provides the approximate number of days of grinding work per tunnel:

$$Work\ days = 2\left(\frac{Length\ of\ tunnel}{Hourly\ production\ rate}\right) / Daily\ track\ time$$

Table #.3 provides unit costs used for the notching work. Table #.4 shows the estimated cost for Cooper Tunnel.

Daylighting Calculating the volume of rock removal from each tunnel in a daylighting scenario required a number of assumptions. First, only tunnels with an overburden of less than 200 feet were considered for daylighting. To simplify the calculations, the overburden profile assumptions employed for the geological investigation in liner removal/crown mining were also applied to daylighting estimates.

Before excavation of the new cut, trees and vegetation must be removed. The cost of this activity is based upon the affected area. The top width of the cut was evaluated by one-foot longitudinal increments to estimate a total area in square feet.

The costs of drilling, blasting, excavating, and spoil removal are related to the volume of overburden. A two part procedure was employed to estimate this volume. First, the volume of a cut containing the tracks was calculated using the well known average-end area method:

$$v_i = \frac{0.5l(A_i + A_{i-1})}{27}$$

where: v_i = volume of section i, yd3;
A_i, A_{i-1} = end cross-section areas of increment section, ft^2; and
l = section length, ft.

The volume of the existing tunnel was then estimated by multiplying the cross-sectional area and length. The total amount of overburden is the difference between the total cut volume and the tunnel volume.

The estimate employs a number of additional assumptions:

- tunnels are straight and have no grade;
- cut slopes are 2:1, without steps;
- to account for ditches, seven additional feet on each side of the ballast shoulder is excavated;
- The cross-sectional area of the cut was treated as a trapezoid. The area, s, of a trapezoid is:

$$s = \frac{1}{2}(a+b)h$$

Table A.3
Tunnel Notching Cost Parameters

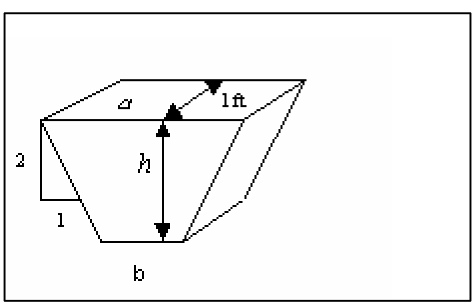
Description	*Unit Cost*	*Location*
Mobilization/Demobilization	10% of Total	Assumed
Engineering Costs	10% of Total	Assumed
Field Engineer	$1,000/ day	Contractor
Exploratory Work	$2,500/ day	Contractor
Clearance Excavation	$175 /ft /notch	Contractor
Ten-Foot Long Rock Bolts	$500 /Bolt	Contractor
Shotcrete with a Thickness of 12 Inches	$650 / yd^3	Contractor
Grout	$142 / yd^3	RS Means
Grout Hole	$10 /Hole	RS Means
Rock Boring	$54 /Lin. Foot	RS Means
Production Rate	25 ft/hr	Contractor
Track Time	5 hrs/ day	Contractor
Mobilization/Demobilization	2 days	Assumed

where: s = Area,
a = Top width,
b = Bottom width, and
h = height.

The bottom width, b, is the base width in feet of the existing tunnel, provided by NS, plus 14 feet to account for ditches. The height in feet of overburden, h, was found from topographic maps. The top width, a, was calculated geometrically using b, h, and the side slope. Figure #.2 depicts the process.

The next step involves calculating the volume of each tunnel. Since the tunnel characteristics are similar, standard cross-sections were developed for single-track and double track tunnels. For single-track tunnels, the general cross-sectional area is:

Figure A.2
Cross-Section of Removed Material



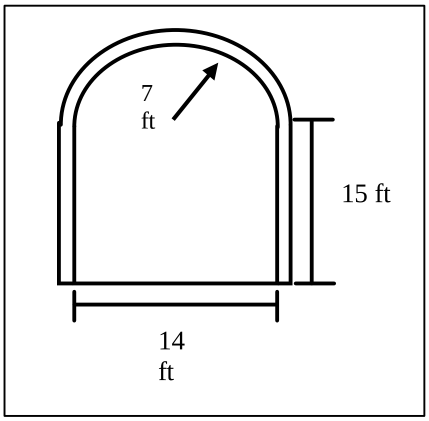
$$(14'\times 15') + (\frac{p(67)^2}{2}) = 287\ \text{ft}^2.$$

This cross-section is depicted in Figure A.3. For double track tunnels, the cross-sectional area is:

$$(15'\times 24') + (\frac{p\,(7)^2}{2}) + (10'\times 7') = 507\ \text{ft}^2.$$

The area was multiplied by the total tunnel length to determine the volume.

Figure A.3
Single Track Tunnel Profile



It was assumed the lining remains freestanding until the excavation is complete. The liner would then be removed, section-by-section, with the railroad still in operation. It was assumed that the tunnel liners are 2 feet thick reinforced concrete. For single-track tunnels, the cross-sectional area of tunnel liner removed, per linear foot of tunnel, was estimated as follows:

$$(h_L + h_R)(l_T) + \frac{p\,(r_A)^2 - p\,(r_B)^2}{2}$$

$$(15\,ft + 15\,ft)(2\,ft) + \frac{p\,(9\,ft)^2 - p\,(7\,ft)^2}{2} = 110.3\,ft^2$$

where:

h_l = height of liner on the left side of the tunnel where the roof begins;
h_r = height of liner on the right side of the tunnel where the roof begins;
l_T = liner thickness;
r_A = radius to top of tunnel crown including liner thickness;
r_B = radius to top of tunnel crown.

For double-track tunnels, the cross-sectional area of tunnel removed, per linear foot of tunnel, was estimated as follows:

$$\left(h_L + h_R\right)\left(l_T\right) + \left(d_t\right)\left(l_t\right) + \frac{p\left(r_A\right)^2 - p\left(r_B\right)^2}{2}$$

$$\left(15\,ft + 15\,ft\right)\left(2\,ft\right) + \left(10\,ft\right)\left(2\,ft\right)\frac{p\left(9\,ft\right)^2 - p\left(7\,ft\right)^2}{2} = 130.3\,ft^2$$

where:

h_l = height of liner on the left side of the tunnel where the roof begins;
h_r = height of liner on the right side of the tunnel where the roof begins;
l_t = liner thickness;
r_A = radius to top of tunnel crown including liner thickness;
r_B = radius to top of tunnel crown;
d_t = track distance between rail lines.

To estimate the cost of removing the tunnel liner, the cross-sectional area of the tunnel liner was multiplied by the tunnel length.

Cost elements and unit costs are summarized in Table A.5. Daylighting costs for Cooper Tunnel may be found in Table A.6.

Table A.5
Daylighting Unit Costs

Description	*Unit Cost*	*Location*
Mobilization/Demobilization	10% of Total	Assumed
Engineering Costs	10% of Total	Assumed
Clear & Grub	$15,275 /Ac	RS Means
Drilling & Blasting	$6 /yd^3	RS Means
Excavate & Load Blasted Rock	$1.32 /yd^3	RS Means
Hauling	$3.18 /yd^3	RS Means
Liner Removal	$35.75 /ft^2/ 1ft	RS Means

Table A.4
Sample Notching Costs–Cooper Tunnel

Item	*Quantity*	*Unit*	*Description*	*Unit Cost*	*Total*
1	1	Lump Sum	Mobilization/Demobilization	$83,577	$83,577
2	1	Lump Sum	Engineering Costs	$83,577	$83,577
3	7	Days	Exploratory Work	$2,500	$17,500
4	23	Days	Field Engineer	$1,000	$23,000
5	698	Linear Feet	Clearance Excavation	$175	$286,180
6	558	Each	Ten-Foot Long Rock Bolts For Notching	$500	$279,200
7	1135	Cubic Yard	Grout	$142	$161,145
8	977	Each	Grout Hole	$10	$9,772
9	1092	Linear Feet	Rock Boring	$54	$58,968
10	1	Lump Sum	Contingency (5%)		$50,146
TOTAL COST FOR ENLARGEMENT					**$1,053,064**

Table A.6
Sample Daylighting Costs–Cooper Tunnel

Item	*Quantity*	*Unit*	*Description*	*Unit Cost*	*Total*
1	1	Lump Sum	Mobilization/Demobilization	$618,121	$618,121
2	1	Lump Sum	Engineering Costs	$618,121	$618,121
3	2.8	Acre	Clear and Grub	$15,275	$42,770
4	417900	Cubic Yard	Drilling and Blasting	$6	$2,507,400
5	417900	Cubic Yard	Excavate and Load Blasted Rock	$1.32	$551,628
6	417900	Cubic Yard	Hauling	$3.18	$1,328,922
7	97929	Square Feet	Liner Removal	$17.88	$1,750,488
8	1	Lump Sum	Contingency (5%)		$370,872
TOTAL COST FOR ENLARGEMENT					**$7,788,322**

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Appendix B

2000 NORFOLK SOUTHERN

410. RAILWAY OPERATING EXPENSES

(Dollars in Thousands)

Line No.	Name of railway operating expense account (a)	Total Freight Expense (f)	Passenger (g)	Total (h)	Factor	Adjusted	Per Revenue Ton-Mile	Per Freight Train Mile	Per Freight Train Hour
1	Track	14,379	0	14,379	0.750	10,784	2.634E-05	0.1449056	2.1063103
2	Bridge & building	4,631	0	4,631	0.750	3,473	8.483E-06	0.0466693	0.6783729
3	Signal	5,898	0	5,898	0.000	0			
4	Communication	6,227	0	6,227	0.000	0			
5	Other	5,572	0	5,572	0.750	4,179	2.116E-05	0.0561523	0.8162154
6	Roadway - running	28,598	0	28,598	0.750	21,449	0.0001086	0.2881988	4.1891831
7	Roadway - switching	1,920	0	1,920	0.000	0			
8	Tunnels & subways - running	495	0	495	0.000	0			
9	Tunnels & subways - switching	2	0	2	0.000	0			
10	Bridges & culverts - running	21,094	0	21,094	0.750	15,821	8.012E-05	0.2125766	3.0899583
11	Bridges & culverts - switching	1,283	0	1,283	0.750	962	4.873E-06	0.0129295	0.1879405
12	Ties - running	5,670	0	5,670	0.750	4,253	2.153E-05	0.0571399	0.8305709
13	Ties - switching	542	0	542	0.000	0			
14	Rail & other track material - running	70,420	0	70,420	0.750	52,815	0.0002675	0.7096635	10.315486
15	Rail & other track material - switching	4,939	0	4,939	0.000	0			
16	Ballast - running	5,668	0	5,668	0.750	4,251	2.153E-05	0.0571198	0.830278
17	Ballast - switching	513	0	513	0.000	0			
18	Road property damaged - running	6,742	0	6,742	0.750	5,057	2.561E-05	0.0679431	0.9876031
19	Road property damaged - switching	0	0	0	0.000	0			
20	Road property damaged - other	19	0	19	0.750	14			
21	Signals & interlockers - running	24,709	0	24,709	0.000	0			
22	Signals & interlockers - switching	1,046	0	1,046	0.000	0			
23	Communications systems	32,189	0	32,189	0.000	0			
24	Power systems	711	0	711	0.000	0			
25	Highway grade crossings - running	(1,284)	0	(1,284)	0.750	-963	-4.88E-06	-0.01294	-0.188087
26	Highway grade crossings - switching	93	0	93	0.000	0			

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27	Station & office buildings	8,343	0	8,343	0.000	0			
28	Shop buildings - locomotives	6,136	0	6,136	0.000	0			
29	Shop buildings - freight cars	2,988	0	2,988	0.000	0			
30	Shop buildings - other equipment	20	0	20	0.000	0			
101	Locomotive servicing facilities	1	0	1	0.000	0			
102	Miscellaneous buildings & structures	2,000	0	2,000	0.000	0			
103	Coal terminals	3,775	0	3,775	0.000	0			
104	Ore terminals	0	0	0	0.000	0			
105	Other marine terminals	0	0	0	0.000	0			
106	TOFC/COFC terminals	8,740	0	8,740	0.000	0			
107	Motor vehicle loading & distribution facilities	372	0	372	0.000	0			
108	Facilities for other specialized service operations	1,019	0	1,019	0.000	0			
109	Roadway machines	19,815	0	19,815	0.750	14,861	7.526E-05	0.1996873	2.9026038
110	Small tools & supplies	19,970	0	19,970	0.750	14,978	7.585E-05	0.2012494	2.925309
111	Snow removal	3,078	0	3,078	0.000	0			
112	Fringe benefits - running	15,233	0	15,233	0.750	11,425	5.786E-05	0.1535119	2.2314087
113	Fringe benefits - switching	2,029	0	2,029	0.000	0			
114	Fringe benefits - other	25,191	0	25,191	0.750	18,893	9.568E-05	0.2538644	3.6901081
115	Casualties & insurance - running	15,898	0	15,898	0.750	11,924	6.038E-05	0.1602134	2.3288213
116	Casualties & insurance - switching	725	0	725	0.000	0			
117	Casualties & insurance - other	8,500	0	8,500	0.750	6,375	3.228E-05	0.0856595	1.245124
118	Lease rentals - debit -running	149,543	0	149,543	0.750	112,157	0.000568	1.5070323	21.905833
119	Lease rentals - debit -switching	202,492	0	202,492	0.000	0			
120	Lease rentals - debit -other	30,753	0	30,753	0.750	23,065	0.0001168	0.309916	4.5048586
121	Lease rentals - (credit) - running	6,194	0	6,194	0.750	4,646	2.353E-05	0.0624206	0.9073292
122	Lease rentals - (credit) - switching	0	0	0	0.000	0			
123	Lease rentals - (credit) - other	0	0	0	0.750	0			
124	Joint facility rent - debit - running	16,814	0	16,814	0.750	12,611	6.386E-05	0.1694445	2.4630018
125	Joint facility rent - debit - switching	686	0	686	0.000	0			
126	Joint facility rent - debit - other	674	0	674	0.750	506	2.56E-06	0.0067923	0.098731
127	Joint facility rent - (credit) - running	8,050	0	8,050	0.750	6,038	3.057E-05	0.0811246	1.1792057
128	Joint facility rent - (credit) - switching	1,828	0	1,828	0.000	0			
129	Joint facility rent - (credit) - other	105	0	105	0.750	79	3.988E-07	0.0010581	0.0153809
130	Other rents - debit - running	2,444	0	2,444	0.750	1,833	9.282E-06	0.0246296	0.3580098
131	Other rents - debit - switching	0	0	0	0.000	0			
132	Other rents - debit - other	989	0	989	0.750	742	3.756E-06	0.0099667	0.1448738
133	Other rents - (credit) - running	0	0	0	0.750	0			
134	Other rents - (credit) - switching	0	0	0	0.000	0			
135	Other rents - (credit) - other	0	0	0	0.750	0			
136	Depreciation - running	164,226	0	164,226	0.750	123,170	0.0006237	1.6550015	24.056675
137	Depreciation - switching	12,953	0	12,953	0.000	0			
138	Depreciation - other	84,856	0	84,856	0.750	63,642	0.0003223	0.8551435	12.430146

139	Joint facility - debit - running	34,737	0	34,737	0.750	26,053	0.0001319	0.3500651	5.0884556
140	Joint facility - debit - switching	671	0	671	0.000	0			
141	Joint facility - debit - other	13	0	13	0.750	10			
142	Joint facility - (credit) - running	24,066	0	24,066	0.750	18,050	9.14E-05	0.2425272	3.5253122
143	Joint facility - (credit) - switching	3,594	0	3,594	0.000	0			
144	Joint facility - (credit) - other	337	0	337	0.750	253	1.28E-06	0.0033961	0.0493655
145	Dismantling retired road property - running	0	0	0	0.750	0			
146	Dismantling retired road property - switching	0	0	0	0.000	0			
147	Dismantling retired road property - other	0	0	0	0.750	0			
148	Other - running	18,834	0	18,834	0.750	14,126	7.153E-05	0.1898012	2.7589018
149	Other - switching	86	0	86	0.000	0			
150	Other - other	(555)	0	(555)	0.750	-416	-2.11E-06	-0.005593	-0.081299
151	**TOTAL WAY & STRUCTURES**	**1,061,951**	**0**	**1,061,951**		**607,109**	**0.0030744**	**8.1572709**	**118.57199**
201	Administration	16,092	0	16,092	2.000	32,184	7.861E-05	0.4324493	6.2859719
202	Repair & maintenance	156,474	0	156,474	2.000	312,948	0.0007643	4.2050134	61.122991
203	Machinery repair	5,575	0	5,575	2.000	11,150	2.723E-05	0.1498201	2.1777463
204	Equipment damaged	1,350	0	1,350	2.000	2,700	6.595E-06	0.0362793	0.5273466
205	Fringe benefits	23,575	0	23,575	2.000	47,150	0.0001152	0.6335442	9.2090347
206	Other casualties & insurance	10,319	0	10,319	2.000	20,638	5.041E-05	0.2773083	4.0308814
207	Lease rentals - debit	129,274	0	129,274	2.000	258,548	0.0006315	3.4740526	50.497932
208	Lease rentals - (credit)	7,916	0	7,916	2.000	15,832	3.867E-05	0.2127311	3.0922044
209	Joint facility rent - debit	(28)	0	(28)	2.000	-56	-1.37E-07	-0.000752	-0.010938
210	Joint facility rent - (credit)	0	0	0	2.000	0			
211	Other rents - debit	32	0	32	2.000	64	1.563E-07	0.00086	0.0125001
212	Other rents - (credit)	32	0	32	2.000	64	1.563E-07	0.00086	0.0125001
213	Depreciation	76,541	0	76,541	2.000	153,082	0.0003739	2.0569291	29.898992
214	Joint facility - debit	20	0	20	2.000	40	9.77E-08	0.0005375	0.0078125
215	Joint facility - (credit)	16	0	16	2.000	32	7.816E-08	0.00043	0.00625
216	Repairs billed to others - (credit)	207	0	207	2.000	414	1.011E-06	0.0055628	0.0808598
217	Dismantling retired property	0	0	0	2.000	0			
218	Other	4,629	0	4,629	2.000	9,258	2.261E-05	0.1243977	1.808213
219	**TOTAL LOCOMOTIVES**	**415,682**	**0**	**415,682**		**864,048**	**0.0043756**	**11.610023**	**168.7603**
220	Administration	19,296	0	19,296	0.930	17,945	9.088E-05	0.2411268	3.5049567
221	Repair & maintenance	117,980	0	117,980	0.930	109,721	0.0005556	1.4743023	21.430078
222	Machinery repair	6,040	0	6,040	0.930	5,617	2.845E-05	0.0754771	1.0971154
223	Equipment damaged	4,115	0	4,115	0.930	3,827	1.938E-05	0.0514219	0.7474553
224	Fringe benefits	14,093	0	14,093	0.930	13,106	6.637E-05	0.176109	2.5598753
225	Other casualties & insurance	12,768	0	12,768	0.930	11,874	6.013E-05	0.1595515	2.3192002
226	Lease rentals - debit	125,912	0	125,912	0.930	117,098	0.000593	1.5734222	22.870859
227	Lease rentals - (credit)	9,941	0	9,941	0.930	9,245	4.682E-05	0.1242248	1.8056993
228	Joint facility rent - debit	52	0	52	0.930	48	2.449E-07	0.0006498	0.0094454

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229	Joint facility rent - (credit)	0	0	0	0.930	0			
230	Other rents - debit	582,877	0	582,877	0.930	542,076	0.0027451	7.2837506	105.87472
231	Other rents - (credit)	233,637	0	233,637	0.930	217,282	0.0011003	2.9195759	42.438203
232	Depreciation	89,484	0	89,484	0.930	83,220	0.0004214	1.1182104	16.254019
233	Joint facility - debit	204	0	204	0.930	190	9.608E-07	0.0025492	0.0370549
234	Joint facility - (credit)	26	0	26	0.930	24	1.224E-07	0.0003249	0.0047227
235	Repairs billed to others - (credit)	44,449	0	44,449	0.930	41,338	0.0002093	0.5554438	8.0737883
236	Dismantling retired property	0	0	0	0.930	0			
237	Other	8,712	0	8,712	0.930	8,102	4.103E-05	0.1088669	1.5824618
238	**TOTAL FREIGHT CARS**	**693,480**	**0**	**1,269,586**		**1,180,715**	**0.0059792**	**15.865007**	**230.60966**
301	Administration	2,391	0	2,391	0.750	1,793	9.081E-06	0.0240955	0.3502461
302	Trucks, trailers, & containers - revenue service	36,466	0	36,466	0.750	27,350	0.0001385	0.3674892	5.3417284
303	Floating equipment - revenue service	0	0	0	0.750	0			
304	Passenger & other revenue equipment	0	0	0	0.750	0			
305	Computers and data processing equipment	25,425	0	25,425	0.750	19,069	9.657E-05	0.2562226	3.7243856
306	Machinery	494	0	494	0.750	371	1.876E-06	0.0049783	0.0723637
307	Work & other non-revenue equipment	8,214	0	8,214	0.750	6,161	3.12E-05	0.0827773	1.2032292
308	Equipment damaged	0	0	0	0.750	0	0		
309	Fringe benefits	1,461	0	1,461	0.750	1,096	5.549E-06	0.0147234	0.2140148
310	Other casualties & insurance	687	0	687	0.750	515	2.609E-06	0.0069233	0.1006353
311	Lease rentals - debit	37,491	0	37,491	0.750	28,118	0.0001424	0.3778187	5.4918757
312	Lease rentals - (credit)	281	0	281	0.750	211	1.067E-06	0.0028318	0.0411623
313	Joint facility rent - debit	21	0	21	0.750	16	7.976E-08	0.0002116	0.0030762
314	Joint facility rent - (credit)	79	0	79	0.750	59	3E-07	0.0007961	0.0115723
315	Other rents - debit	57,168	0	57,168	0.750	42,876	0.0002171	0.5761154	8.3742645
316	Other rents - (credit)	17,889	0	17,889	0.750	13,417	6.794E-05	0.1802779	2.6204733
317	Depreciation	75,371	0	75,371	0.750	56,528	0.0002863	0.7595577	11.040734
318	Joint facility - debit	100	0	100	0.750	75	3.798E-07	0.0010078	0.0146485
319	Joint facility - (credit)	(6)	0	(6)	0.750	-5	-2.28E-08	-6.05E-05	-0.000879
320	Repairs billed to others - (credit)	8,633	0	8,633	0.750	6,475	3.279E-05	0.0869998	1.2646065
321	Dismantling retired property	0	0	0	0.750	0	0		
322	Other	3	0	3	0.750	2	1.139E-08	3.023E-05	0.0004395
323	**TOTAL OTHER EQUIPMENT**	**218,416**	**0**	**218,416**		**204,126**	**0.0010337**	**2.7427961**	**39.868577**
324	TOTAL EQUIPMENT	1,327,578	0	1,327,578					
401	Administration	72,465	0	72,465	1.000	72,465	0.000367	0.9736963	14.153398
402	Engine crews	271,714	0	271,714	0.750	203,786	0.001032	2.7382209	39.802073
403	Train crews	273,096	0	273,096	0.750	204,822	0.0010372	2.7521481	40.004516
404	Dispatching trains	33,789	0	33,789	1.000	33,789	0.0001711	0.4540154	6.5994502
405	Operating signals & interlockers	22,814	0	22,814	1.000	22,814	0.0001155	0.3065467	4.4558837
406	Operating drawbridges	4,853	0	4,853	1.000	4,853	2.458E-05	0.0652087	0.9478567
407	Highway crossing protection	4,554	0	4,554	1.000	4,554	2.306E-05	0.0611911	0.889458

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408	Train inspection & lubrication	52,468	0	52,468	1.000	52,468	0.0002657	0.705001	10.247712
409	Locomotive fuel	440,192	0	440,192	2.500	1,100,480	0.0055729	14.786908	214.93868
410	Electric power produced or purchased for motive	0	0	0	1.000	0			
411	Servicing locomotives	29,801	0	29,801	1.000	29,801	0.0001509	0.4004295	5.8205396
412	Freight lost or damaged - solely related	0	0	0	1.000	0			
413	Clearing wrecks	8,575	0	8,575	1.000	8,575	4.342E-05	0.1152204	1.6748138
414	Fringe benefits	211,926	0	211,926	1.000	211,926	0.0010732	2.847603	41.392023
415	Other casualties & insurance	50,121	0	50,121	1.000	50,121	0.0002538	0.6734648	9.7893113
416	Joint facility - debit	3,835	0	3,835	1.000	3,835	1.942E-05	0.0515301	0.7490275
417	Joint facility - (credit)	1,383	0	1,383	1.000	1,383	7.004E-06	0.0185831	0.2701187
418	Other	86,438	0	86,438	1.000	86,438	0.0004377	1.1614484	16.882514
419	**TOTAL TRAIN OPERATIONS**	**1,565,258**	**0**	**1,565,258**		**2,092,110**	**0.0105945**	**28.111215**	**408.61737**
420	Administration	12,735	0	12,735	0.000	0			
421	Switch crews	195,870	0	195,870	0.000	0			
422	Controlling operations	26,896	0	26,896	0.000	0			
423	Yard and terminal clerical	33,583	0	33,583	0.000	0			
424	Oper. switches, signals, retarders, & humps	731	0	731	0.000	0			
425	Locomotive fuel	37,496	0	37,496	0.000	0			
426	Electric power produced or purchased for motive	0	0	0	0.000	0			
427	Servicing locomotives	701	0	701	0.000	0			
428	Freight lost or damaged - solely related	0	0	0	0.000	0			
429	Clearing wrecks	314	0	314	0.000	0			
430	Fringe benefits	89,263	0	89,263	0.000	0			
431	Other casualties & insurance	17,822	0	17,822	0.000	0			
432	Joint facility - debit	3,726	0	3,726	0.000	0			
433	Joint facility - (credit)	2,394	0	2,394	0.000	0			
434	Other	1	0	1	0.000	0			
435	**TOTAL YARD OPERATIONS**	**416,744**	**0**	**416,744**		**0**			
501	Cleaning car interiors	1,322	0	1,322	0.000	0			
502	Adjusting & transferring loads	348	0	348	0.000	0			
503	Car loading devices & grain docks	2	0	2	0.000	0			
504	Freight lost or damaged - all other	18,305	0	18,305	0.000	0			
505	Fringe benefits	148	0	148	0.000	0			
506	**TOTAL TRAIN & YARD OPNS. COMMON**	**20,125**	**0**	**20,125**		**0**			
507	Administration	34,265	0	34,265	0.500	17,133	8.676E-05	0.2302056	3.3462097
508	Pickup & delivery and marine line haul	124,988	0	124,988	0.000	0			
509	Loading & unloading and local marine	155,986	0	155,986	0.000	0			
510	Protective services	797	0	797	0.500	399	2.018E-06	0.0053546	0.0778325
511	Freight lost or damaged - solely related	0	0	0	0.500	0			
512	Fringe benefits	13,522	0	13,522	0.500	6,761	3.424E-05	0.0908461	1.320515
513	Casualties & insurance	2,732	0	2,732	0.500	1,366	6.917E-06	0.0183546	0.2667983

514	Joint facility - debit	464	0	464	0.500	232	1.175E-06	0.0031173	0.0453127
515	Joint facility - (credit)	1	0	1	0.500	1	2.532E-09	6.718E-06	9.766E-05
516	Other	0	0	0	0.500	0			
517	**TOTAL SPECIALIZED SERVICE OPERATIONS**	**332,753**	**0**	**332,753**			**0.0001311**	**0.3478849**	**5.0567659**
518	Administration	5,815	0	5,815	0.000	0			
519	Employees performing clerical & accntg. functions	40,275	0	40,275	0.000	0			
520	Communication systems operations	3,566	0	3,566	0.000	0			
521	Loss & damage claims processing	1,710	0	1,710	0.000	0			
522	Fringe benefits	17,572	0	17,572	0.000	0			
523	Casualties & insurance	3,518	0	3,518	0.000	0			
524	Joint facility - debit	14	0	14	0.000	0			
525	Joint facility - (credit)	0	0	0	0.000	0			
526	Other	0	0	0	0.000	0			
527	**TOTAL ADMIN SUPPORT OPNS.**	**72,470**	**0**	**72,470**		**0**			
528	TOTAL TRANSPORTATION	2,407,350	0	2,407,350					
601	Officers - general administration	7,496	0	7,496	0.000	0			
602	Accounting, auditing, & finance	21,045	0	21,045	0.000	0			
603	Management services & data processing	31,805	0	31,805	0.000	0			
604	Marketing	17,747	0	17,747	0.000	0			
605	Sales	4,911	0	4,911	0.000	0			
606	Industrial development	2,015	0	2,015	0.000	0			
607	Personnel & labor relations	17,899	0	17,899	0.000	0			
608	Legal & secretarial	42,412	0	42,412	0.000	0			
609	Public relations & advertising	5,396	0	5,396	0.000	0			
610	Research & development	0	0	0	0.000	0			
611	Fringe benefits	94,028	0	94,028	0.000	0			
612	Casualties & insurance	866	0	866	0.000	0			
613	Writedown of uncollectible accounts	20,865	0	20,865	0.000	0			
614	Property taxes	101,651	0	101,651	0.000	0			
615	Other taxes except on corporate income or payroll	36,684	0	36,684	0.000	0			
616	Joint facility - debit	858	0	858	0.000	0			
617	Joint facility - (credit)	(28)	0	(28)	0.000	0			
618	Other	462,616	0	462,616	0.000	0			
619	TOTAL GENERAL & ADMIN.	868,322	0	868,322					
620	TOTAL CARRIER OPERATING EXPENSES	5,665,201	0	5,665,201					

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330. ROAD PROPERTY AND EQUIPMENT AND IMPROVEMENTS TO LEASED PROPERTY AND EQUIPMENT
(Dollars in Thousands)

Line No.	5,119,972	Balance at Beginning of year (b)	Net changes during the year Net changes during the year (g)	Balance at close of year (h)	Factor	Adjusted	Annual	Per Revenue Ton-Mile	Per Freight Train Mile	Per Freight Train Hour
1	Land for transportation purposes	194,686	7,837	202,523	0.000	0	0			
2	Grading	502,184	17,959	520,143	0.000	0	0			
3	Other right-of-way expenditures	5,306	76	5,382	0.000	0	0			
4	Tunnels and subways	45,417	(4,664)	40,753	0.000	0	0			
5	Bridges, trestles and culverts	730,743	20,068	750,811	0.000	0	0			
6	Elevated structures	38,015	(201)	37,814	0.000	0	0			
7	Ties	1,879,347	77,595	1,956,942	0.676	1,322,893	66,145	0.00033	0.888771	12.918946
8	Rail and other track material	2,787,496	110,913	2,898,409	0.676	1,959,324	97,966	0.00050	1.3163506	19.134133
9	Ballast	798,371	36,721	835,092	0.676	564,522	28,226	0.00014	0.379268	5.5129422
10	Fences, snowsheds and signs	6,439	(14)	6,425	1.000	0	0			
11	Station and office buildings	400,449	23,716	424,165	0.000	0	0			
12	Roadway buildings	44,582	140	44,722	0.000	0	0			
13	Water stations	0	0	0	0.000	0	0			
14	Fuel stations	20,690	18	20,708	0.000	0	0			
15	Shops and enginehouses	176,289	4,257	180,546	0.000	0	0			
16	Storage warehouses	4,143	19	4,162	0.000	0	0			
17	Wharves and docks	2,833	0	2,833	0.000	0	0			
18	Coal and ore wharves	138,482	8,993	147,475	0.000	0	0			
19	TOFC/COFC terminals	179,338	4,573	183,911	0.000	0	0			
20	Communications systems	345,064	7,854	352,918	0.000	0	0			
21	Signals and interlockers	544,404	34,555	578,959	0.000	0	0			
22	Power plants	2,678	(2)	2,676	0.000	0	0			
23	Power transmission systems	22,094	978	23,072	0.000	0	0			
24	Miscellaneous structures	13,766	36	13,802	0.000	0	0			
25	Roadway machines	231,218	21,070	252,288	0.676	170,547	8,527	0.00004	0.1145799	1.6655041
26	Public improvements - construction	241,350	14,020	255,370	0.000	0	0			
27	Shop machinery	82,998	2,975	85,973	0.000	0	0			
28	Power plant machinery	14,806	0	14,806	0.000	0	0			
29	Other lease/rentals	0	0	0	0.676	0	0			
30	**TOTAL EXPENDITURES FOR ROAD**	**9,453,188**	**389,492**	**9,842,680**		**4,017,286**	**200,864**	**0.00102**	**2.69897**	**39.23152**
31	Locomotives	2,014,490	6,742	2,021,232	0.676	1,366,353	68,318	0.00035	0.9179691	13.343362
32	Freight train cars	2,777,898	(13,748)	2,764,150	1.000	2,764,150	138,208	0.00070	1.8570638	26.9938

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33	Passenger train cars	0	0	0	0.000	0	0			
34	Highway revenue equipment	147,435	(22,669)	124,766	0.676	84,342	4,217	0.00002	0.0566641	0.8236551
35	Floating equipment	644	0	644	1.000	644	32	0.00000	0.0004327	0.0062891
36	Work equipment	141,046	(1,710)	139,336	0.676	94,191	4,710	0.00002	0.0632813	0.9198403
37	Miscellaneous equipment	162,041	1,742	163,783	0.676	110,717	5,536	0.00003	0.0743842	1.0812296
38	Computer systems & word processing equipment	265,210	4,323	269,533	0.000	0	0			
39	**TOTAL EXPENDITURES FOR EQUIPMENT**	**5,508,764**	**(25,320)**	**5,483,444**		**4,420,397**	**221,020**	**0.00112**	**2.96980**	**43.16818**
40	Interest during construction	0	0	0	0.000	0	0			
41	Other elements of investment	0	0	0	0.000	0	0			
42	Construction work in progress	296,356	10,312	306,668	0.000	0	0			
43	**GRAND TOTAL**	**15,258,308**	**374,484**	**15,632,792**		**8,437,683**	**421,884**	**0.00214**	**5.66876**	**82.39970**

Appendix C

CHICAGO	
Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	4.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS	
Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	4.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
Discount Rate	6.125%

Year	**Chicago 1Stack Containers**	**Annual Transport Savings Chicago 1Stack**	**Chicago 2Stack Containers**	**Annual Transport Savings Chicago 2Stack**	**Columbus Containers**	**Annual Transport Savings Columbus**	**Annual Inventory Savings**	**Total Annual Savings**
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	740,124	12,286,928
2	24,826	$6,995,956	57,928	3,794,878	10,982	1,275,576	773,430	12,839,839
3	25,944	$7,310,774	60,535	3,965,648	11,476	1,332,977	808,234	13,417,632
4	27,111	$7,639,759	63,259	4,144,102	11,993	1,392,961	844,605	14,021,426
5	28,331	$7,983,548	66,106	4,330,586	12,532	1,455,644	882,612	14,652,390
6	29,606	$8,342,807	69,080	4,525,463	13,096	1,521,148	922,330	15,311,747
7	30,938	$8,718,234	72,189	4,729,108	13,685	1,589,599	963,834	16,000,776
8	32,330	$9,110,554	75,438	4,941,918	14,301	1,661,131	1,007,207	16,720,811
9	33,785	$9,520,529	78,832	5,164,305	14,945	1,735,882	1,052,531	17,473,247
10	35,306	$9,948,953	82,380	5,396,698	15,617	1,813,997	1,099,895	18,259,544
11	36,894	$10,396,656	86,087	5,639,550	16,320	1,895,627	1,149,391	19,081,223
12	38,555	$10,864,505	89,961	5,893,330	17,055	1,980,930	1,201,113	19,939,878
13	40,290	$11,353,408	94,009	6,158,529	17,822	2,070,072	1,255,163	20,837,173
14	42,103	$11,864,311	98,239	6,435,663	18,624	2,163,225	1,311,646	21,774,845
15	43,997	$12,398,205	102,660	6,725,268	19,462	2,260,570	1,370,670	22,754,713
16	45,977	$12,956,125	107,280	7,027,905	20,338	2,362,296	1,432,350	23,778,675
17	48,046	$13,539,150	112,107	7,344,161	21,253	2,468,599	1,496,805	24,848,716
18	50,208	$14,148,412	117,152	7,674,648	22,209	2,579,686	1,564,162	25,966,908
19	52,467	$14,785,091	122,424	8,020,007	23,209	2,695,772	1,634,549	27,135,419
20	54,829	$15,450,420	127,933	8,380,908	24,253	2,817,082	1,988,888	28,637,297
	56,199	10,501,105	86,952	5,696,207	16,484	1,914,671	2,391,068	19,286,959
	745,300	210,022,090	1,739,034	113,924,137	329,682	38,293,421	23,499,539	385,739,188
		109,394,982		**59,340,086**		**19,946,036**	**12,179,549**	**200,860,653**

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CHICAGO	
Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	6.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS	
Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	6.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
Discount Rate	6.125%

Year	**Chicago 1Stack Containers**	**Annual Transport Savings Chicago 1Stack**	**Chicago 2Stack Containers**	**Annual Transport Savings Chicago 2Stack**	**Columbus Containers**	**Annual Transport Savings Columbus**	**Annual Inventory Savings**	**Total Annual Savings**
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	740,124	12,286,928
2	25,302	$7,129,850	59,037	3,867,507	11,192	1,299,989	788,232	13,085,578
3	26,946	$7,593,290	62,874	4,118,895	11,920	1,384,488	839,468	13,936,141
4	28,698	$8,086,854	66,961	4,386,623	12,694	1,474,480	894,033	14,841,990
5	30,563	$8,612,499	71,314	4,671,754	13,519	1,570,321	952,145	15,806,719
6	32,550	$9,172,312	75,949	4,975,418	14,398	1,672,392	1,014,035	16,834,156
7	34,665	$9,768,512	80,886	5,298,820	15,334	1,781,097	1,079,947	17,928,376
8	36,919	$10,403,465	86,143	5,643,243	16,331	1,896,868	1,150,143	19,093,720
9	39,318	$11,079,690	91,743	6,010,054	17,392	2,020,165	1,224,903	20,334,812
10	41,874	$11,799,870	97,706	6,400,708	18,523	2,151,476	1,304,521	21,656,575
11	44,596	$12,566,862	104,057	6,816,754	19,727	2,291,322	1,389,315	23,064,252
12	47,494	$13,383,708	110,820	7,259,843	21,009	2,440,257	1,479,621	24,563,429
13	50,582	$14,253,649	118,024	7,731,733	22,375	2,598,874	1,575,796	26,160,052
14	53,869	$15,180,136	125,695	8,234,295	23,829	2,767,801	1,678,223	27,860,455
15	57,371	$16,166,845	133,865	8,769,524	25,378	2,947,708	1,787,307	29,671,385
16	61,100	$17,217,690	142,567	9,339,544	27,027	3,139,309	1,903,482	31,600,025
17	65,071	$18,336,840	151,833	9,946,614	28,784	3,343,364	2,027,209	33,654,026
18	69,301	$19,528,734	161,703	10,593,144	30,655	3,560,683	2,158,977	35,841,538
19	73,806	$20,798,102	172,213	11,281,698	32,648	3,792,127	2,299,311	38,171,238
20	78,603	$22,149,978	183,407	12,015,008	34,770	4,038,615	2,448,766	40,652,368
	80,568	12,996,179	107,612	7,049,632	20,401	2,369,599	2,959,188	23,852,188
	922,385	259,923,579	2,152,231	140,992,642	408,015	47,391,982	28,735,557	477,043,761
		130,492,628		**70,784,269**		**23,792,779**	**14,426,465**	**239,496,140**

CHICAGO

Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	8.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS

Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	8.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
Discount Rate	6.125%

Year	Chicago 1Stack Containers	Annual Transport Savings Chicago 1Stack	Chicago 2Stack Containers	Annual Transport Savings Chicago 2Stack	Columbus Containers	Annual Transport Savings Columbus	Annual Inventory Savings	Total Annual Savings
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	740,124	12,286,928
2	25,777	$7,263,743	60,146	3,940,137	11,402	1,324,402	803,035	13,331,317
3	27,968	$7,881,162	65,258	4,275,048	12,371	1,436,976	871,293	14,464,478
4	30,345	$8,551,060	70,805	4,638,427	13,423	1,559,119	945,353	15,693,959
5	32,924	$9,277,901	76,823	5,032,694	14,564	1,691,644	1,025,708	17,027,946
6	35,723	$10,066,522	83,353	5,460,472	15,802	1,835,433	1,112,893	18,475,321
7	38,759	$10,922,176	90,438	5,924,613	17,145	1,991,445	1,207,489	20,045,723
8	42,054	$11,850,562	98,126	6,428,205	18,602	2,160,718	1,310,125	21,749,610
9	45,628	$12,857,859	106,466	6,974,602	20,184	2,344,379	1,421,486	23,598,327
10	49,507	$13,950,777	115,516	7,567,443	21,899	2,543,651	1,542,312	25,604,184
11	53,715	$15,136,593	125,335	8,210,676	23,761	2,759,862	1,673,409	27,780,540
12	58,281	$16,423,204	135,988	8,908,583	25,780	2,994,450	1,815,649	30,141,886
13	63,234	$17,819,176	147,547	9,665,813	27,972	3,248,978	1,969,979	32,703,946
14	68,609	$19,333,806	160,089	10,487,407	30,349	3,525,141	2,137,427	35,483,782
15	74,441	$20,977,180	173,696	11,378,837	32,929	3,824,778	2,319,108	38,499,903
16	80,769	$22,760,240	188,460	12,346,038	35,728	4,149,885	2,516,233	41,772,395
17	87,634	$24,694,860	204,479	13,395,451	38,765	4,502,625	2,730,112	45,323,049
18	95,083	$26,793,923	221,860	14,534,064	42,060	4,885,348	2,962,172	49,175,508
19	103,165	$29,071,407	240,718	15,769,460	45,635	5,300,603	3,213,957	53,355,426
20	111,934	$31,542,476	261,179	17,109,864	49,514	5,751,154	3,487,143	57,890,637
	114,732	16,193,466	134,086	8,783,965	25,420	2,952,562	3,687,200	29,720,243
	1,149,307	323,869,323	2,681,717	175,679,297	508,394	59,051,238	35,805,007	594,404,864
		156,959,785		**85,141,082**		**28,618,547**	**17,352,512**	**288,071,926**

CHICAGO

Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	4.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS

Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	4.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
J28Discount Rate	6.125%

DETROIT

Base Number of Containers	20,985
Percent Single Stack	0%
Traffic Growth Rate	4.5%
Route Mile Savings	74
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$34.38
J28Discount Rate	6.125%

Year	Chicago 1Stack Containers	Annual Transport Savings Chicago 1Stack	Chicago 2Stack Containers	Annual Transport Savings Chicago 2Stack	Columbus Containers	Annual Transport Savings Columbus	Detroit Containers	Annual Transport Savings Detroit	Annual Inventory Savings	Total Annual Savings
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	20,985	721,488	975,655	13,243,946
2	24,826	$6,995,956	57,928	3,794,878	10,982	1,275,576	21,929	753,955	1,019,559	13,839,924
3	25,944	$7,310,774	60,535	3,965,648	11,476	1,332,977	22,916	787,883	1,065,439	14,462,720
4	27,111	$7,639,759	63,259	4,144,102	11,993	1,392,961	23,947	823,338	1,113,384	15,113,543
5	28,331	$7,983,548	66,106	4,330,586	12,532	1,455,644	25,025	860,388	1,163,486	15,793,652
6	29,606	$8,342,807	69,080	4,525,463	13,096	1,521,148	26,151	899,106	1,215,843	16,504,367
7	30,938	$8,718,234	72,189	4,729,108	13,685	1,589,599	27,328	939,565	1,270,556	17,247,063
8	32,330	$9,110,554	75,438	4,941,918	14,301	1,661,131	28,558	981,846	1,327,731	18,023,181
9	33,785	$9,520,529	78,832	5,164,305	14,945	1,735,882	29,843	1,026,029	1,387,479	18,834,224
10	35,306	$9,948,953	82,380	5,396,698	15,617	1,813,997	31,186	1,072,200	1,449,916	19,681,764
11	36,894	$10,396,656	86,087	5,639,550	16,320	1,895,627	32,589	1,120,449	1,515,162	20,567,444
12	38,555	$10,864,505	89,961	5,893,330	17,055	1,980,930	34,056	1,170,869	1,583,344	21,492,979
13	40,290	$11,353,408	94,009	6,158,529	17,822	2,070,072	35,588	1,223,558	1,654,595	22,460,163
14	42,103	$11,864,311	98,239	6,435,663	18,624	2,163,225	37,190	1,278,619	1,729,052	23,470,870
15	43,997	$12,398,205	102,660	6,725,268	19,462	2,260,570	38,863	1,336,156	1,806,859	24,527,059
16	45,977	$12,956,125	107,280	7,027,905	20,338	2,362,296	40,612	1,396,283	1,888,168	25,630,777
17	48,046	$13,539,150	112,107	7,344,161	21,253	2,468,599	42,439	1,459,116	1,973,135	26,784,162
18	50,208	$14,148,412	117,152	7,674,648	22,209	2,579,686	44,349	1,524,776	2,061,926	27,989,449
19	52,467	$14,785,091	122,424	8,020,007	23,209	2,695,772	46,345	1,593,391	2,154,713	29,248,974
20	54,829	$15,450,420	127,933	8,380,908	24,253	2,817,082	48,430	1,665,094	2,251,675	30,565,178
	56,199	10,501,105	86,952	5,696,207	16,484	1,914,671	32,916	1,131,706	1,530,384	20,774,072
	745,300	210,022,090	1,739,034	113,924,137	329,682	38,293,421	658,329	22,634,112	30,607,678	415,481,439
		109,394,982		**59,340,086**		**19,946,036**		**11,789,514**	**15,942,735**	**216,413,352**

CHICAGO

Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	6.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS

Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	6.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
J28Discount Rate	6.125%

DETROIT

Base Number of Containers	20,985
Percent Single Stack	0%
Traffic Growth Rate	6.5%
Route Mile Savings	74
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$34.38
J28Discount Rate	6.125%

Year	Chicago 1Stack Containers	Annual Transport Savings Chicago 1Stack	Chicago 2Stack Containers	Annual Transport Savings Chicago 2Stack	Columbus Containers	Annual Transport Savings Columbus	Detroit Containers	Annual Transport Savings Detroit	Annual Inventory Savings	Total Annual Savings
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	20,985	721,488	975,655	13,243,946
2	25,302	$7,129,850	59,037	3,867,507	11,192	1,299,989	22,349	768,385	1,039,072	14,104,803
3	26,946	$7,593,290	62,874	4,118,895	11,920	1,384,488	23,802	818,330	1,106,612	15,021,615
4	28,698	$8,086,854	66,961	4,386,623	12,694	1,474,480	25,349	871,521	1,178,542	15,998,020
5	30,563	$8,612,499	71,314	4,671,754	13,519	1,570,321	26,996	928,170	1,255,147	17,037,891
6	32,550	$9,172,312	75,949	4,975,418	14,398	1,672,392	28,751	988,501	1,336,732	18,145,354
7	34,665	$9,768,512	80,886	5,298,820	15,334	1,781,097	30,620	1,052,754	1,423,619	19,324,802
8	36,919	$10,403,465	86,143	5,643,243	16,331	1,896,868	32,610	1,121,183	1,516,154	20,580,914
9	39,318	$11,079,690	91,743	6,010,054	17,392	2,020,165	34,730	1,194,060	1,614,704	21,918,674
10	41,874	$11,799,870	97,706	6,400,708	18,523	2,151,476	36,988	1,271,674	1,719,660	23,343,388
11	44,596	$12,566,862	104,057	6,816,754	19,727	2,291,322	39,392	1,354,333	1,831,438	24,860,708
12	47,494	$13,383,708	110,820	7,259,843	21,009	2,440,257	41,952	1,442,364	1,950,482	26,476,654
13	50,582	$14,253,649	118,024	7,731,733	22,375	2,598,874	44,679	1,536,118	2,077,263	28,197,636
14	53,869	$15,180,136	125,695	8,234,295	23,829	2,767,801	47,583	1,635,966	2,212,285	30,030,483
15	57,371	$16,166,845	133,865	8,769,524	25,378	2,947,708	50,676	1,742,303	2,356,084	31,982,464
16	61,100	$17,217,690	142,567	9,339,544	27,027	3,139,309	53,970	1,855,553	2,509,229	34,061,324
17	65,071	$18,336,840	151,833	9,946,614	28,784	3,343,364	57,478	1,976,164	2,672,329	36,275,310
18	69,301	$19,528,734	161,703	10,593,144	30,655	3,560,683	61,214	2,104,615	2,846,030	38,633,205
19	73,806	$20,798,102	172,213	11,281,698	32,648	3,792,127	65,193	2,241,415	3,031,022	41,144,364
20	78,603	$22,149,978	183,407	12,015,008	34,770	4,038,615	69,431	2,387,106	3,228,039	43,818,747
	80,568	12,996,179	107,612	7,049,632	20,401	2,369,599	40,737	1,400,600	1,894,005	25,710,015
	922,385	259,923,579	2,152,231	140,992,642	408,015	47,391,982	814,749	28,012,003	37,880,098	514,200,304
		130,492,628		**70,784,269**		**23,792,779**		**14,063,210**	**19,017,411**	**258,150,296**

.

CHICAGO

Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	8.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS

Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	8.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
Discount Rate	6.125%

DETROIT

Base Number of Containers	20,985
Percent Single Stack	0%
Traffic Growth Rate	8.5%
Route Mile Savings	74
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$34.38
J28Discount Rate	6.125%

Year	Chicago 1Stack Containers	Annual Transport Savings Chicago 1Stack	Chicago 2Stack Containers	Annual Transport Savings Chicago 2Stack	Columbus Containers	Annual Transport Savings Columbus	Detroit Containers	Annual Transport Savings Detroit	Annual Inventory Savings	Total Annual Savings
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	20,985	721,488	975,655	13,243,946
2	25,777	$7,263,743	60,146	3,940,137	11,402	1,324,402	22,769	782,815	1,058,585	14,369,682
3	27,968	$7,881,162	65,258	4,275,048	12,371	1,436,976	24,704	849,354	1,148,565	15,591,105
4	30,345	$8,551,060	70,805	4,638,427	13,423	1,559,119	26,804	921,549	1,246,193	16,916,349
5	32,924	$9,277,901	76,823	5,032,694	14,564	1,691,644	29,082	999,881	1,352,120	18,354,238
6	35,723	$10,066,522	83,353	5,460,472	15,802	1,835,433	31,554	1,084,871	1,467,050	19,914,348
7	38,759	$10,922,176	90,438	5,924,613	17,145	1,991,445	34,236	1,177,085	1,591,749	21,607,068
8	42,054	$11,850,562	98,126	6,428,205	18,602	2,160,718	37,146	1,277,137	1,727,048	23,443,669
9	45,628	$12,857,859	106,466	6,974,602	20,184	2,344,379	40,304	1,385,693	1,873,847	25,436,381
10	49,507	$13,950,777	115,516	7,567,443	21,899	2,543,651	43,730	1,503,477	2,033,124	27,598,473
11	53,715	$15,136,593	125,335	8,210,676	23,761	2,759,862	47,447	1,631,273	2,205,939	29,944,343
12	58,281	$16,423,204	135,988	8,908,583	25,780	2,994,450	51,480	1,769,931	2,393,444	32,489,613
13	63,234	$17,819,176	147,547	9,665,813	27,972	3,248,978	55,855	1,920,375	2,596,887	35,251,230
14	68,609	$19,333,806	160,089	10,487,407	30,349	3,525,141	60,603	2,083,607	2,817,622	38,247,584
15	74,441	$20,977,180	173,696	11,378,837	32,929	3,824,778	65,754	2,260,714	3,057,120	41,498,629
16	80,769	$22,760,240	188,460	12,346,038	35,728	4,149,885	71,344	2,452,874	3,316,975	45,026,012
17	87,634	$24,694,860	204,479	13,395,451	38,765	4,502,625	77,408	2,661,369	3,598,918	48,853,223
18	95,083	$26,793,923	221,860	14,534,064	42,060	4,885,348	83,987	2,887,585	3,904,826	53,005,747
19	103,165	$29,071,407	240,718	15,769,460	45,635	5,300,603	91,126	3,133,030	4,236,737	57,511,236
20	111,934	$31,542,476	261,179	17,109,864	49,514	5,751,154	98,872	3,399,337	4,596,859	62,399,691
	114,732	16,193,466	134,086	8,783,965	25,420	2,952,562	50,760	1,745,172	2,359,963	32,035,128
	1,149,307	323,869,323	2,681,717	175,679,297	508,394	59,051,238	1,015,192	34,903,445	47,199,264	640,702,567
		156,959,785		**85,141,082**		**28,618,547**		**16,915,579**	**22,874,616**	**310,509,609**

CHICAGO

Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	4.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS

Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	4.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
Discount Rate	6.125%

DETROIT

Base Number of Containers	20,985
Percent Single Stack	0%
Traffic Growth Rate	4.5%
Route Mile Savings	74
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$34.38
Discount Rate	6.125%

WEST VIRGINIA

Base Number of Containers	11,252
Percent Single Stack	0%
Traffic Growth Rate	4.5%
Route Mile Savings	491
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$228.12
Discount Rate	6.125%

Year	Chicago 1Stack Containers	Annual Transport Savings Chicago 1Stack	Chicago 2Stack Containers	Annual Transport Savings Chicago 2Stack	Columbus Containers	Annual Transport Savings Columbus	Detroit Containers	Annual Transport Savings Detroit	WV Containers	Annual Transport Savings WV	Annual Inventory Savings	Total Annual Savings
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	20,985	721,488	10,725	2,446,625	975,655	15,690,571
2	24,826	$6,995,956	57,928	3,794,878	10,982	1,275,576	21,929	753,955	11,208	2,556,723	1,019,559	16,396,647
3	25,944	$7,310,774	60,535	3,965,648	11,476	1,332,977	22,916	787,883	11,712	2,671,775	1,065,439	17,134,496
4	27,111	$7,639,759	63,259	4,144,102	11,993	1,392,961	23,947	823,338	12,239	2,792,005	1,113,384	17,905,548
5	28,331	$7,983,548	66,106	4,330,586	12,532	1,455,644	25,025	860,388	12,790	2,917,645	1,163,486	18,711,298
6	29,606	$8,342,807	69,080	4,525,463	13,096	1,521,148	26,151	899,106	13,365	3,048,939	1,215,843	19,553,306
7	30,938	$8,718,234	72,189	4,729,108	13,685	1,589,599	27,328	939,565	13,967	3,186,142	1,270,556	20,433,205
8	32,330	$9,110,554	75,438	4,941,918	14,301	1,661,131	28,558	981,846	14,595	3,329,518	1,327,731	21,352,699
9	33,785	$9,520,529	78,832	5,164,305	14,945	1,735,882	29,843	1,026,029	15,252	3,479,346	1,387,479	22,313,571
10	35,306	$9,948,953	82,380	5,396,698	15,617	1,813,997	31,186	1,072,200	15,938	3,635,917	1,449,916	23,317,681
11	36,894	$10,396,656	86,087	5,639,550	16,320	1,895,627	32,589	1,120,449	16,656	3,799,533	1,515,162	24,366,977
12	38,555	$10,864,505	89,961	5,893,330	17,055	1,980,930	34,056	1,170,869	17,405	3,970,512	1,583,344	25,463,491
13	40,290	$11,353,408	94,009	6,158,529	17,822	2,070,072	35,588	1,223,558	18,188	4,149,185	1,654,595	26,609,348
14	42,103	$11,864,311	98,239	6,435,663	18,624	2,163,225	37,190	1,278,619	19,007	4,335,899	1,729,052	27,806,769
15	43,997	$12,398,205	102,660	6,725,268	19,462	2,260,570	38,863	1,336,156	19,862	4,531,014	1,806,859	29,058,073
16	45,977	$12,956,125	107,280	7,027,905	20,338	2,362,296	40,612	1,396,283	20,756	4,734,910	1,888,168	30,365,687
17	48,046	$13,539,150	112,107	7,344,161	21,253	2,468,599	42,439	1,459,116	21,690	4,947,981	1,973,135	31,732,142
18	50,208	$14,148,412	117,152	7,674,648	22,209	2,579,686	44,349	1,524,776	22,666	5,170,640	2,061,926	33,160,089
19	52,467	$14,785,091	122,424	8,020,007	23,209	2,695,772	46,345	1,593,391	23,686	5,403,319	2,154,713	34,652,293
20	54,829	$15,450,420	127,933	8,380,908	24,253	2,817,082	48,430	1,665,094	24,752	5,646,468	2,251,675	36,211,646
	56,199	10,501,105	86,952	5,696,207	16,484	1,914,671	32,916	1,131,706		3,837,705	1,530,384	24,611,777
	745,300	210,022,090	1,739,034	113,924,137	329,682	38,293,421	658,329	22,634,112		76,754,096	30,607,678	492,235,535
		109,394,982		**59,340,086**		**19,946,036**		**11,789,514**		**39,979,190**	**15,942,735**	**256,392,542**

CHICAGO

Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	6.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS

Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	6.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
Discount Rate	6.125%

DETROIT

Base Number of Containers	20,985
Percent Single Stack	0%
Traffic Growth Rate	6.5%
Route Mile Savings	74
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$34.38
Discount Rate	6.125%

WEST VIRGINIA

Base Number of Containers	11,252
Percent Single Stack	0%
Traffic Growth Rate	6.5%
Route Mile Savings	491
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$228.12
Discount Rate	6.125%

Year	**Chicago 1Stack Containers**	**Annual Transport Savings Chicago 1Stack**	**Chicago 2Stack Containers**	**Annual Transport Savings Chicago 2Stack**	**Columbus Containers**	**Annual Transport Savings Columbus**	**Detroit Containers**	**Annual Transport Savings Detroit**	**WV Containers**	**Annual Transport Savings WV**	**Annual Inventory Savings**	**Total Annual Savings**
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	20,985	721,488	10,725	2,446,625	975,655	15,690,571
2	25,302	$7,129,850	59,037	3,867,507	11,192	1,299,989	22,349	768,385	11,422	2,605,655	1,039,072	16,710,458
3	26,946	$7,593,290	62,874	4,118,895	11,920	1,384,488	23,802	818,330	12,165	2,775,023	1,106,612	17,796,638
4	28,698	$8,086,854	66,961	4,386,623	12,694	1,474,480	25,349	871,521	12,955	2,955,399	1,178,542	18,953,419
5	30,563	$8,612,499	71,314	4,671,754	13,519	1,570,321	26,996	928,170	13,797	3,147,500	1,255,147	20,185,392
6	32,550	$9,172,312	75,949	4,975,418	14,398	1,672,392	28,751	988,501	14,694	3,352,088	1,336,732	21,497,442
7	34,665	$9,768,512	80,886	5,298,820	15,334	1,781,097	30,620	1,052,754	15,649	3,569,974	1,423,619	22,894,776
8	36,919	$10,403,465	86,143	5,643,243	16,331	1,896,868	32,610	1,121,183	16,667	3,802,022	1,516,154	24,382,936
9	39,318	$11,079,690	91,743	6,010,054	17,392	2,020,165	34,730	1,194,060	17,750	4,049,153	1,614,704	25,967,827
10	41,874	$11,799,870	97,706	6,400,708	18,523	2,151,476	36,988	1,271,674	18,904	4,312,348	1,719,660	27,655,736
11	44,596	$12,566,862	104,057	6,816,754	19,727	2,291,322	39,392	1,354,333	20,132	4,592,651	1,831,438	29,453,359
12	47,494	$13,383,708	110,820	7,259,843	21,009	2,440,257	41,952	1,442,364	21,441	4,891,173	1,950,482	31,367,827
13	50,582	$14,253,649	118,024	7,731,733	22,375	2,598,874	44,679	1,536,118	22,835	5,209,099	2,077,263	33,406,736
14	53,869	$15,180,136	125,695	8,234,295	23,829	2,767,801	47,583	1,635,966	24,319	5,547,691	2,212,285	35,578,173
15	57,371	$16,166,845	133,865	8,769,524	25,378	2,947,708	50,676	1,742,303	25,900	5,908,291	2,356,084	37,890,755
16	61,100	$17,217,690	142,567	9,339,544	27,027	3,139,309	53,970	1,855,553	27,583	6,292,330	2,509,229	40,353,654
17	65,071	$18,336,840	151,833	9,946,614	28,784	3,343,364	57,478	1,976,164	29,376	6,701,331	2,672,329	42,976,641
18	69,301	$19,528,734	161,703	10,593,144	30,655	3,560,683	61,214	2,104,615	31,285	7,136,918	2,846,030	45,770,123
19	73,806	$20,798,102	172,213	11,281,698	32,648	3,792,127	65,193	2,241,415	33,319	7,600,817	3,031,022	48,745,181
20	78,603	$22,149,978	183,407	12,015,008	34,770	4,038,615	69,431	2,387,106	35,485	8,094,870	3,228,039	51,913,618
	80,568	12,996,179	107,612	7,049,632	20,401	2,369,599	40,737	1,400,600		4,749,548	1,894,005	30,459,563
	922,385	259,923,579	2,152,231	140,992,642	408,015	47,391,982	814,749	28,012,003		94,990,957	37,880,098	609,191,261
		130,492,628		**70,784,269**		**23,792,779**		**14,063,210**		**47,689,477**	**19,017,411**	**305,839,773**

CHICAGO

Base Number of Containers	79,191
Percent Single Stack	30%
Traffic Growth Rate	8.5%
Route Mile Savings (2Stack)	141
Per Ton-Mile Cost (2Stack)	$0.027
Per Ton-Mile Cost (1Stack)	$0.043
Tons Per Container	17.0
Per Container Savings (2Stack)	$65.51
Per Container Savings (1Stack)	$281.80
Discount Rate	6.125%

COLUMBUS

Base Number of Containers	10,509
Percent Single Stack	0%
Traffic Growth Rate	8.5%
Route Mile Savings	250
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$116.15
Discount Rate	6.125%

DETROIT

Base Number of Containers	20,985
Percent Single Stack	0%
Traffic Growth Rate	8.5%
Route Mile Savings	74
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$34.38
Discount Rate	6.125%

WEST VIRGINIA

Base Number of Containers	11,252
Percent Single Stack	0%
Traffic Growth Rate	8.5%
Route Mile Savings	491
Per Ton-Mile Cost	$0.027
Tons Per Container	17.0
Per Container Savings	$228.12
Discount Rate	6.125%

Year	Chicago 1Stack Containers	Annual Transport Savings Chicago 1Stack	Chicago 2Stack Containers	Annual Transport Savings Chicago 2Stack	Columbus Containers	Annual Transport Savings Columbus	Detroit Containers	Annual Transport Savings Detroit	WV Containers	Annual Transport Savings WV	Annual Inventory Savings	Total Annual Savings
1	23,757	$6,694,694	55,434	3,631,462	10,509	1,220,647	20,985	721,488	10,725	2,446,625	975,655	15,690,571
2	25,777	$7,263,743	60,146	3,940,137	11,402	1,324,402	22,769	782,815	11,637	2,654,588	1,058,585	17,024,270
3	27,968	$7,881,162	65,258	4,275,048	12,371	1,436,976	24,704	849,354	12,626	2,880,228	1,148,565	18,471,332
4	30,345	$8,551,060	70,805	4,638,427	13,423	1,559,119	26,804	921,549	13,699	3,125,047	1,246,193	20,041,396
5	32,924	$9,277,901	76,823	5,032,694	14,564	1,691,644	29,082	999,881	14,863	3,390,676	1,352,120	21,744,914
6	35,723	$10,066,522	83,353	5,460,472	15,802	1,835,433	31,554	1,084,871	16,127	3,678,884	1,467,050	23,593,232
7	38,759	$10,922,176	90,438	5,924,613	17,145	1,991,445	34,236	1,177,085	17,497	3,991,589	1,591,749	25,598,657
8	42,054	$11,850,562	98,126	6,428,205	18,602	2,160,718	37,146	1,277,137	18,985	4,330,874	1,727,048	27,774,543
9	45,628	$12,857,859	106,466	6,974,602	20,184	2,344,379	40,304	1,385,693	20,598	4,698,998	1,873,847	30,135,379
10	49,507	$13,950,777	115,516	7,567,443	21,899	2,543,651	43,730	1,503,477	22,349	5,098,413	2,033,124	32,696,886
11	53,715	$15,136,593	125,335	8,210,676	23,761	2,759,862	47,447	1,631,273	24,249	5,531,778	2,205,939	35,476,121
12	58,281	$16,423,204	135,988	8,908,583	25,780	2,994,450	51,480	1,769,931	26,310	6,001,979	2,393,444	38,491,591
13	63,234	$17,819,176	147,547	9,665,813	27,972	3,248,978	55,855	1,920,375	28,547	6,512,147	2,596,887	41,763,377
14	68,609	$19,333,806	160,089	10,487,407	30,349	3,525,141	60,603	2,083,607	30,973	7,065,680	2,817,622	45,313,264
15	74,441	$20,977,180	173,696	11,378,837	32,929	3,824,778	65,754	2,260,714	33,606	7,666,262	3,057,120	49,164,891
16	80,769	$22,760,240	188,460	12,346,038	35,728	4,149,885	71,344	2,452,874	36,462	8,317,895	3,316,975	53,343,907
17	87,634	$24,694,860	204,479	13,395,451	38,765	4,502,625	77,408	2,661,369	39,562	9,024,916	3,598,918	57,878,139
18	95,083	$26,793,923	221,860	14,534,064	42,060	4,885,348	83,987	2,887,585	42,924	9,792,034	3,904,826	62,797,781
19	103,165	$29,071,407	240,718	15,769,460	45,635	5,300,603	91,126	3,133,030	46,573	10,624,356	4,236,737	68,135,592
20	111,934	$31,542,476	261,179	17,109,864	49,514	5,751,154	98,872	3,399,337	50,532	11,527,427	4,596,859	73,927,118
	114,732	16,193,466	134,086	8,783,965	25,420	2,952,562	50,760	1,745,172		5,918,020	2,359,963	37,953,148
	1,149,307	323,869,323	2,681,717	175,679,297	508,394	59,051,238	1,015,192	34,903,445		118,360,393	47,199,264	759,062,959
		156,959,785		**85,141,082**		**28,618,547**		**16,915,579**		**57,362,092**	**22,874,616**	**367,871,701**