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Freight Rail Project Evaluation- An Inventory-Theoretic Approach to Logistics Costs

Saravanya Sankarakumaraswamy[a], Sharada Vadali[b,*], Anne Goodchild[c], Kenneth Kuhn[d]

[a] *SCTL Center, University of Washington, Box 352700, Seattle, Washington, USA.*
[b] *Economic Insights and Research, College Station, Texas, USA.*
[c] *SCTL Center, University of Washington, Box 352700, Seattle, Washington, USA.*
[d] *RAND Corporation, Santa Monica, California, USA.*

Abstract

Abstract: This work develops and applies a novel approach to logistics cost estimation for a freight rail project based on a case study conducted as part of a recently completed research project completed for the National Cooperative Freight Research Program Project (NCFRP). This article discusses the application of the methodology developed as part of NCFRP to the analysis of a multijurisdictional rail project in the United States- the Heartland Corridor project. The approach relies only on leveraging publicly available and open data sources to support preliminary social return on investment and feasibility analysis via Cost-Benefit Analysis (CBA) to address problems associated with availability of input data. This specific paper relies on the Freight Analysis Framework, Surface Transportation Board's Uniform Railroad Costing System data, and data on Class 1 rail track miles operated from American Association of Railroad. These sources are combined to provide commodity specific logistics costs comprising of transport, inventory, loading and unloading costs and damage costs suitable for use in CBA. This approach to logistics cost estimation allows for a more comprehensive breakdown of the cost of shipping between origin-destination pairs than the conventional approach of focusing on transportation specific metrics like travel time savings which rely on availability of suitable values of time for freight (and value of reliability), operating costs savings and inventory savings. The project's intermodal terminals and line-haul double-stacking improvements also can induce truck-diversion to rail to take advantage of shipping efficiencies in an effect that is independent from the effects of capacity enhancement. The main contributions of this work can be listed as the following: (1) demonstrate the applicability of the inventory theory approach to CBA in general and for rail in particular (2) demonstrate the use of open source and publicly available data in the U.S to approximate logistics cost savings and (3) provide an approach for modal diversion estimation from freight investments for freight rail projects Finally, (4) the analysis relies on the use of Monte Carlo simulation in the net present value (NPV) to account for the uncertainty in parameters and input data.

* Corresponding author. Tel.: +1-979-220-1270
E-mail address: sharada.vadali@gmail.com

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1. Introduction

Freight rail projects intended to support the movement of freight cargo between markets are often multijurisdictional in nature, meaning they cross through multiple geographic jurisdictions and hence involve several stakeholders at the local, state and regional levels from multiple jurisdictions. Multi-jurisdictional freight projects can improve efficiency and other benefits such as providing better access to economic centres and global markets, (Ross and Woo, 2011). In the United States, such projects are evaluated for federal funding/grant eligibility (under the discretionary grant programs[†]) or to meet legislative requirements in some U.S states like in Washington state, Pennsylvania and Florida. Similarly, there are other examples and guidance on conducting CBA from across the world for meeting funding eligibility (as in Australia, Europe, New Zealand) (see Rowengold 2013 for examples from California, Cambridge Systematics et al., 2011, and Vadali et al., 2017) and (see Ernst and Young, 2017 for a recent Australian example). A key issue is that there is a lack of a consistency and transparency across the studies, few recognize the need and value of conducting rapid feasibility analysis. Finally, many rely on the conventional approach of valuing travel time savings based on crew costs alone, operating costs and only sometimes consider inventory savings for cargo in transit.

A preliminary feasibility study also known as a preliminary business case study helps to determine if further analysis is required or not and, in some situations, maybe the only CBA ever conducted for evaluating whether a project is grant worthy. It uses existing data sets that are easily available and with reasonable assumptions for evaluating projects of any scale and type (public or private). A multijurisdictional Cost-Benefit Analysis (CBA) identifies the strengths and weaknesses of projects that move freight through several geographic jurisdictions or projects that have partners from different jurisdictional entities (Vadali et al., 2017). The following section discusses some of the important challenges arising in the context of the multi-jurisdictional projects especially rail projects in the U.S context.

1.1 Challenges in the Evaluation of Multijurisdictional Projects

The challenges in evaluating multijurisdictional freight rail projects can be identified as the following: 1) Compiling input activity data i.e. freight flows for existing network (base flows) 2) diversion (new user flows) and 3) Developing defensible estimation of all costs. 4) Addressing distributional aspects for the aggregate costs and benefits in calculation. For instance, if there are large scale network improvements like going from single stack to double stack, there are many efficiencies that do not get captured such as productivity and logistics efficiency metrics (Vadali et al., 2017).

[†] For instance, under the Build grants (the earlier Transportation Investment Generating Economic Recovery program) The FAST Act establishes the Nationally Significant Freight and Highway Projects (NSFHP) program to provide competitive grants, known as INFRA grants, —to nationally and regionally significant freight and highway projects that align with critical economic goals.

1.1.1 Compilation of Input/Volume Activity Data for the Build and No-Build Cases

Freight rail projects present unique challenges since even base no-build case rail network volumes as activity data for all rail classes are considered highly confidential. Limited or no access to real data complicates the process of projecting the effect of alternatives as well as forecasting those out into the future.

Limited data availability has been identified in the past as one of the primary challenges in performing CBA (Darcy and VanLandingham, 2015). Evaluating rail network improvements require that rail networks and flows on those networks are available. This information is generally available with rail carriers in the United States (which are privately held) and in some cases rail network improvements can be coded and modelled with access to complicated rail simulation models like Rail Traffic Controller, and Systra's RailSim (see Vadali et al. 2017). Similarly, there is additional informational asymmetry associated with cargo flows using the rail networks since actual commodity flows and networks are closely guarded by the private sector who compete with other private rail carriers and with truck freight. This should not come as a surprise since the rail carrier sector in the United States is highly consolidated with around 4-5 firms controlling the majority of rail traffic, following deregulation. Many of the available data sets such as Freight Analysis Framework and the Surface Transportation Board's public Waybill provide freight movements at a very high level because rail assignments for origin-destination pairs for large areas is difficult due to lack of data on private rail movement information and the process requires additional simulation exercises. Such aggregated data that would be of more use to practitioners aiming in performing an early-stage benefit-cost analyses but more detailed studies can benefit from confidential commodity flow data and network specific data that is held in the private domain. This paper suggests that available public domain data can be down-scaled, by making assumptions, to make it more useful in this context.

1.1.2 Assessing Modal Diversion Potential to Rail

A second challenge is to determine potential new user demand resulting from diversion. This determination can be even more difficult for multijurisdictional projects due to unique circumstances of each origin-destination pair. The need to consider diversion potential complicates a multijurisdictional project further by bringing in multi-modal aspects like the possibility of rail induced efficiencies creating incentives for truck-based cargo to shift to take advantage of the intramodality. In the case of completely new modes, such diversion potential is typically estimated via stated preference or even revealed preference methods. However, a preliminary feasibility analysis and the nature of the improvement often preclude the development of such cost-and time intensive modal choice estimation (Vadali et al, 2017). An alternative is to rely on a consensus estimate from a comprehensive literature review of past cross-modal choice elasticities. For instance, Clark et al, 2005 identify truck to rail and rail to truck diversion studies and range of elasticities for different commodity types.

1.1.3 Individual Assessment of Several Individual Time or Distance Based Cost Considerations on the Benefit Side

On the benefit side, a comprehensive inclusion of all components of variable cost savings for rail (or those that are sensitive to distance or time) such as conventional fuel operating costs and track related maintenance cost, pecuniary logistics costs associated with terminal loading and unloading, and separate costs associated with cargo or freight can also be challenging. With respect to the former, the inclusion of time-based utilization metrics brings up the issue of suitable valuation measures like values of time and reliability to monetize the metrics. While crew time is the most easily and typically addressed, there is continuing debate on what the right valuation measures are for the users of rail-the freight that moves in it. More importantly, a preliminary feasibility assessment also precludes the development of suitable time-based measures of schedule frequency and reliability- a consequence of lack of required data. This paper and the associated report that the paper builds on, proposes conventional inventory theory as the framework (Baumol and Vinod, 1970) for approximating these different cost components. Parts of this framework have been separately adopted in well-known models like the Federal Highway Administration's Highway Economic Requirements

System for highways and Intermodal Transportation and Inventory Costing model (ITIC). This approach will be further discussed in the methodology section of the paper.

1.1.4 Maintaining Transparency

Following Farrow and Zerbe, 2013, it is very important to maintain transparency and state the assumptions made in calculations. The quality of data inputs is an important factor in assessing the results of CBA as it impacts both the cost and benefits side of CBA.

1.1.5 Addressing Uncertainty

The need to include risk and uncertainty becomes an important criterion while producing CBA results especially in the case of multijurisdictional and multimodal freight rail investments remains important even in preliminary studies. This is due to the varying sources of data and information and assumptions used. Commonly used risk and uncertainty techniques include Sensitivity testing and Monte Carlo Simulation (Vadali et al., 2017).

Our work demonstrates an approach that is conceptual and transparent for the evaluation of the logistics cost savings and modal diversion for a multijurisdictional freight rail project. In order to illustrate the approach, we use prominent public private partnership freight rail corridor project like the Heartland Corridor. The contribution to the literature and the hallmark of the approach is the recourse to inventory theory relying entirely on a transparent approach and public domain data sources. This case example will be used to illustrate many of the aforementioned challenges in conducting a multijurisdictional freight project CBA.

1.3 Case Study: Heartland Corridor

We have discussed the evaluation of the Heartland Corridor project in this paper as a case study to demonstrate the approach and challenges. The Heartland Corridor is well known example of a multi-jurisdictional public-private freight rail corridor project in the United States. It was the first multistate public-private rail project involving the Norfolk Southern railways, Federal Highway Administration and the three U.S. states of Virginia, West Virginia and Ohio. It aimed at improving the rail freight operations between the Port of Norfolk and the important Midwest destinations of Columbus and Chicago. The Heartland Corridor project was part of a route rationalization plan where old unprofitable routes were abandoned in favor of more lucrative options primarily due to the nature of large sunk costs of investment. This strategy was a consequence of Staggers Act deregulation and was also adopted by the airline industry. In addition, the move to double stack carried the potential of resulting in cost and time benefits to shippers. The existing single stack rail was improved to double stack and hence the capacity of the freight rail is improved resulting in efficiency of the rail corridor for shippers. The project costs are known and does not have any uncertainty involved. The benefits such as logistics cost savings are derived from public data sources and hence include uncertainties that need to be analyzed further for risk. In this paper, for conducting the conceptual level of Cost Benefit Analysis (CBA) on the case project, we use several public domain data and information such as Freight Analysis Framework. market share assumptions extracted from several open sources of information, to convert the aggregate form of data into network specific data and use that as a base for all our cost savings calculation.

This paper is organized in the following manner. Section 2 presents the methodology. Section 3 presents the case study description with the data sources, assumptions and parameters description and the important results obtained from the CBA. Section 4 discusses the summary and conclusion from the work. The results and tables from the study are presented in detail in the Appendix section.

2. Methodology

2.1 Inventory Approach to Logistics Cost

The focus of our work is to demonstrate the process of developing benefit estimates especially the logistics cost savings associated with a multijurisdictional freight rail project preliminary feasibility CBA that leverages public domain data and information. The extant literature and numerous CBA's found in support of federal grants in the literature lack a consistent framework to address the logistics cost change for a multijurisdictional freight rail project in particular. The approach below is not specific to rail and is applicable to all modes, however, it is being applied in the context of a freight rail project.

The total logistics cost of a transportation mode is given as the sum of transportation cost, inventory carrying cost and any other cost associated with the freight carrier (Sheffi at al. 1988). The most general form of an inventory theory approach to a simple total logistics costs (LC per unit) of any transport mode (based on the concept of lead time *t*) is given by Equation 1 (Sheffi et al., 1988; Tyworth, 1991; Tyworth and Grenoble, 1991; Tyworth et al., 1991; Tyworth and Zeng, 1998):

$$LC = TC + [(1/V) \times (L/2) \times c_{val} \times h] + [t \times c_{val} \times (h/365)] + [(1/V) \times c_{val} \times h \times S \times \text{sqrt}((t \times d_v) + (d^2 + t_v))] \quad (1)$$

Equation 1 identifies four logistics characteristics for any transportation mode, such as transportation costs (TC) ($/unit), loading capacity (L) (units), average lead-time (t) (days), and variance of lead-time (t_v) (days^2). The first term is transportation related costs (TC, which refers to direct transportation costs and can be comprised of several components including fuel, other operating costs like track and locomotive maintenance costs, handling and receiving costs (including loading and unloading), and they may also include freight charges for different modes especially for international shipments which rely on multiple modes. In some cases, TC can also be expanded to included external costs of transport like environmental externalities. Tyworth and Zhang, 1998 propose a simple TC formulation as given by (freight rate per unit x annual demand x weight per unit) which is also the shipping cost. It is this latter formulation, that this paper exploits in the context of a freight rail project and expands to include line haul cost elements like maintenance and those associated with fixed nodes like terminal related handling costs. This approach is made possible entirely by access to detailed Class 1 rail carrier operating statistics made available by the Surface Transportation Board (Schedule R1) and the associated Uniform Rail Costing Software (URCS) database (Surface Transportation Board (www.stb.gov). The Uniform Rail Costing System developed by the Surface Transportation Board is currently the accepted model to estimate variable and total unit costs for Class I U.S. railroads.

The second term refers to the costs of cycle stock. On average, half the shipment size, *L*/2, is in cycle stock. Multiplying this quantity with the value of the goods and the holding cost, *h*, gives the annual costs of cycle stock. When divided by the annual volume, V, it yields the costs of cycle stock per unit (ton, container, etc.). The third term represents the costs of inventory in transit, which depends on the average lead-time, t, and consequently on the speed or transit time of the transport mode. The in-transit inventory carrying cost is the opportunity cost of holding inventory in transit. Cargo valued c_{val} while in transit for t days incurs a carrying cost of h/365 (per day), where h is the holding cost. The holding cost h is sometimes approximated by annual opportunity cost of capital expressed as a percentage of the value of the product. Holding costs can be higher in the case of cargo that is perishable or is associated with high safety costs[‡]. These inventory costs are therefore dependent on the transit time service level of the transportation modal alternative. The last term is the costs of safety stock. The expression under the square root represents the

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‡ The holding or carrying cost is in turn comprised of three components: a) Cost of Capital (to finance inventory), b) costs of storage and handling the inventory and c) Cost or risk (insurance, pilferage, obsolescence etc).

standard deviation of demand during lead-time. It applies only if there is independence both between lead-time and daily demand and between successive daily demands (Blauwens *et al.*, 2002; Allen *et al.*, 1985; Zinn *et al.*, 1992). The safety parameter *S* depends on the tolerated risk of running out of stock during the lead-time, which is specified beforehand by the service agreement between shipper and receiver. This is also dependent on t and speed of the mode.

A typical CBA consumer surplus approximation examines the impact of a transport intervention (policy or project) on a variety of "benefit categories" or impacts by examining a do-nothing base alternative and do-something alternative. Using the LC equation from above, only three of four logistic costs components are relevant for consideration in a CBA, since cycle stock is time invariant. They are TC, inventory costs and safety stock. The analysis will be conducted for a given origin-destination (OD) pair to keep comparisons meaningful. Also, in order to keep the focus on NPV of the project, we restrict ourselves to the consideration of transport and inventory costs.

In this paper, we present a standard approach for preliminary feasibility analysis that leverages public databases and can be improved by recourse to expensive private sector databases such as TRANSEARCH, as well as confidential Waybill data. The approach can be used to estimate logistics cost savings for freight rail projects by demonstrating modal diversion using public data sources. Surface Transportation Board's Uniform Railroad Costing System (URCS) tool is used as an approximation to the transportation costs in above logistics cost equation. In the spirit of the preliminary and conceptual nature of the CBA, the analysis also approximates consumer surplus for potential new system users by leveraging existing modal diversion studies. This is also a cost-effective option to rely on when an expansion to an existing system is the proposed improvement, instead of a whole new modal choice option. The benefits are calculated for the freight flow between an origin-destination pair impacted by the multijurisdictional rail project. The available public domain rail freight data provides the flow of goods between various origin-destination zones or states. Hence, the calculations for CBA are conducted for all origin-destination pairs impacted by the project. While not the focus of this papers, the Schedule R1 operating statistics and URCS database are also the basis for rate making in the railroad industry and their value in providing justifiable rates has been debated. However, the particular use in this case example i.e., the comparison of relative cost differences (rather than absolute levels) of the same cargo across CBA alternatives justifies the reliance on URCS.

Joseph et al. (2007) discusses the benefits of rail freight compared to trucks in reducing highway congestion and provides considerations for transportation planners. The author has presented a feasibility study approach for few example cases such as Pennsylvania double-stack clearance project, Alameda Corridor and few others. The paper presents only a feasibility study approach but have not considered a multi-state project. As noted earlier, when evaluating multijurisdictional rail freight projects, the diversion volume estimation is also important. Diversion from one mode of transport to another for freight is a function of time, cost and service quality influences as well as several logistics related costs as shown in Equation 1 [Hensher, 2001, FHWA ITIC model]. Diversion is evaluated by using different models such as market segmentation, modal elasticity, rules of thumb (for truck to rail), mode choice models (for new modes) and travel models (see Vadali et al., 2017). We propose two different approaches of modal diversion estimation in this paper. Our method uses public data sources only to quantify modal diversion, shipping cost and inventory carrying cost savings. All the cost calculations are performed using Excel worksheet and hence can be easily integrated for any freight related projects and freight transportation mode. We discuss some of the challenges we encounter in this process and how we overcome those with a case study description in the rest of the paper. After a careful review of existing literature related to logistics cost estimation for freight related projects, we found that they do not directly provide a methodology to evaluate logistics cost savings for rail projects and for a multijurisdictional scale. In this paper, we have developed a novel approach that can be used as a guideline for evaluating logistics costs savings for freight projects. We demonstrate the approach for rail mode in this paper which can be easily applied to other mode types and modal diversions as well.

2.2.2 Consumer Surplus Approximation of Logistic Costs

The consumer surplus approximation is given by benefits to existing users (shippers) who use rail in the no-build + benefits to new users of the improved rail facility (via modal diversion) (and rule of the half). Using the logistics cost equation, it is estimated by shipping cost savings (to existing users), shipping cost savings (to new users) and inventory carrying cost savings to shippers. These components will be discussed in detail in later sections of this paper. We use shipping cost savings and other operating cost savings as the main driver of benefits since reliability or service based benefits are difficult to measure as it requires information on arrival times, speed, delay etc. By using the shipping cost and inventory carrying cost savings as the metrics for time related savings, we account for the reliability/security and safety, perishability and obsolescence of cargo. Reliability in terms of time are not easily measurable due to availability of specific data and information.

The measures used to evaluate these changes or benefits are transportation economic efficiency (TEE) metrics and are considered as the first-order benefits in the Benefit-Cost Analysis of freight projects (see Table 5).

2.2.3 Inventory Cost Savings

In this work, we account for the estimation of inventory carrying cost savings as a result of the benefits through travel or transit time reduction. These are calculated as cargo transit savings and based on estimated travel times. The method uses commodity-specific daily discount rates, and the savings in cost are calculated for the total value of goods transported. Discount rates are used to denote the value of the commodity that is being held as inventory over a period of time e.g., 15% for perishable, 5% for bulk and 10% for all other commodity types. The formula in below is used in estimating the inventory cost savings. These rates are approximated by an obsolescence and loss and damage adjustment (following Richardson, 1995) to the prime rate, which is assumed as the base cost of capital. In principle, more complex and theoretically more appropriate cost of capital could be used, however, the Federal prime rate (3.35%) is used in this analysis as the base.

Inventory Carrying Cost Savings = Commodity Value (in $) x Daily Discount Rate x Transit Time Saved (2)

Table 1. Daily discount rate for commodity types.

Commodity type	Daily discount rates
Perishable	0.111643836
Bulk	0.051643836
Other	0.071643836

The daily discount rates are substituted in the formula given in Equation (2) and the results obtained are tabulated and presented in Appendix D Table D 1.

2.2.4 Leverage Public Domain Freight Flow Data

As a preliminary analysis, a critical aspect of the method relies on use of public domain freight flows like those available in Freight Analysis Framework (FAF) and the Waybill. In particular, this research explores FAF's use specifically. The advantages of FAF is that it multimodal (available for rail and other modes) and is continually maintained and updated by the FHWA on an annual basis. The disadvantage is that it's forecasts do not consider the effect of new modes on its forecasts. A feature of all such databases in incremental analysis like CBA is the difficulty of approximating the effects of a no-build counterfactual. While a caveat as such, this feature is likely to persist even with more expensive private data bases. Hence, we restrict ourselves to the use of public domain data. We address other aspects of unmeasured effects and scenarios on freight flows and diversion via an uncertainty/sensitivity analysis approach that is subsequently solved by Monte Carlo Simulation.

2.2.5 Benefits Assessment

A first step in evaluating this project is to present the build and no-build alternatives. The no-build alternative is assumed to be the continuation of the status quo rail connections as they currently exist, while the build alternative includes all the planned double-stacked rail improvement specifications for the Heartland corridor. An important next step in estimating these benefits or cost savings is to develop the input activity data, i.e. the base network commodity flows (existing) and the new user commodity flows (modal diversion) for the rail corridor. In the case of Heartland Corridor that is the subject case study, an origin-destination (O-D) breakdown is used. Three key (O-D) pairs- Norfolk-Chicago, Norfolk-Columbus and Norfolk-Detroit are explored in the paper separately. For each of these O-D pairs, the base network and new user freight flows are to be estimated. FAF was used to obtain the rail freight flow data in terms of weight and value for the O-D pairs. 'Rail' and 'Multiple modes and Mail' were selected from the FAF data to provide the rail mode and the intermodal volumes flowing through the O-D pairs.

The next step is the estimation of cost changes and benefits of the rail project for each of the O-D pairs. Estimation components of variable costs (that are sensitive to distance or time) is targeted. As stated before, comprehensive inclusion of all the variable costs may not be feasible always owing to the availability of data resources.

The benefits related to efficiencies are triggered by the reduction in distance between the O-D pairs and the cost reductions are from the reduction in the variable costs of firms shipping cargo on rail. For rail projects that enhances capacity by improving the existing rail link often leads to modal diversion. Modal diversion is a sign that new users of the upgraded (rail or other) system are accruing time and/or cost benefits because of the project.

3. Case Study

3.1 Description of the Heartland Corridor Project

The Heartland Corridor (HC) project (see Fig. 1.) is a public private partnership between the Norfolk Southern railway, the Federal Highway Administration and the U.S. states of Virginia, West Virginia and Ohio for improving freight rail connectivity from the Port of Virginia to the Mid-west. The project involved raising clearances in the corridor to enable double stacking and distance reduction. It also included construction of three intermodal terminals at key locations; Prichard, Roanoke, and Rickenbacker.

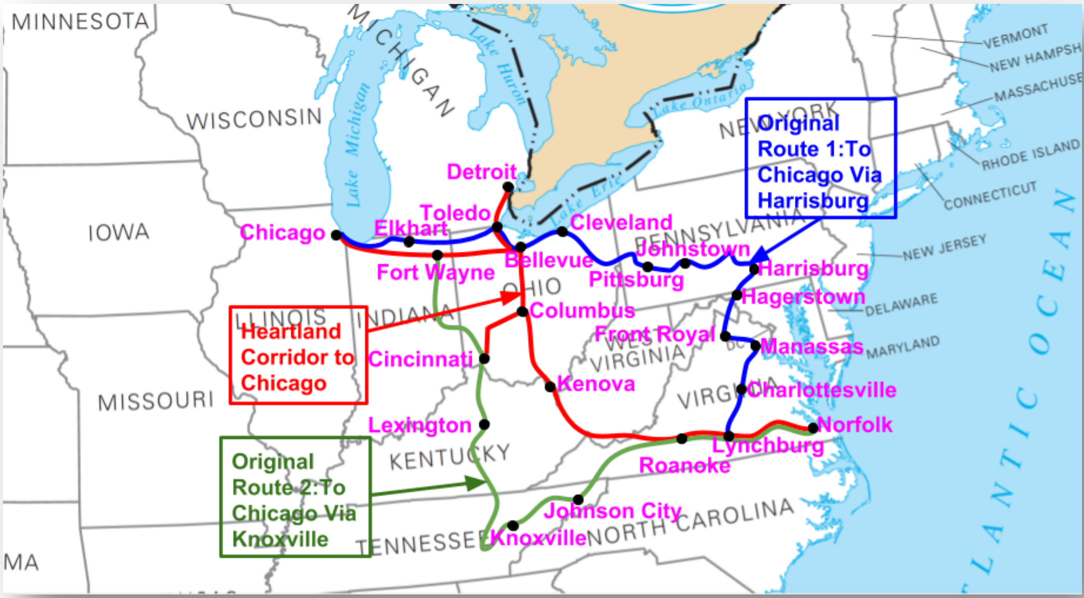

Fig. 1. Heartland Corridor and its original alternate routes (Base map source: U.S. Geological Survey).

It was also the first multi-state public-private rail corridor project in the United States. Construction began in 2007 and involved raising clearances in 28 tunnels and 24 other overhead obstacles. About 5.7 miles of tunnels were modified. The upgraded rail route opened for operation in September 2010. It is a direct high capacity rail route facilitating double-stacked intermodal trains between peripheral regions in Virginia and West Virginia and core Midwest markets. It has reduced the length of the rail line from Norfolk to Chicago by about 200 miles and decreased transit time by one day, thus providing cost and time benefits for shippers. In addition, the corridor helps by reducing tractor-trailer traffic from mode diversion. The overall project features include the following individual projects aimed at improving mobility and freight capacity: (1) Central Corridor Double-Stack Clearance Project; (2) A new intermodal facility in Prichard, West Virginia; (3) A new intermodal facility in the Roanoke region of Virginia; (4) New state-of-the-art mega-intermodal facility at the former Rickenbacker Airport in Columbus, Ohio; (5) Relocation of the Commonwealth Railway into the median of the Western Freeway in Portsmouth, Virginia; and (6) Extension to Cincinnati. The Rickenbacker terminal has been operational since 2008. Prichard opened in December 2015, and the Roanoke terminal is still in the planning stages. Another part of this project includes the relocation of the Commonwealth railway into the median of the western freeway in Portsmouth, Virginia.

3.2 Data sources for cost estimation

Public domain data are the main source for this work. The various data sources used for the estimation of logistics cost savings are provided in Table 2 The use of various data in the actual cost estimation steps in the model framework is shown in Fig. 2. These data are available free to the public. The information from these sources were used to develop the basic estimates for the logistics cost calculations. The data available are aggregate in nature as discussed below. We make reasonable assumptions to disaggregate the data and assign them to select O-D pairs to calculate specific cost and benefit estimates. These assumptions add to the transparency of the CBA itself. The assumptions used for this process are discussed in Section 3.3.

Table 2 Public data sources available for analysis.

Data source	Use in cost savings evaluation
1. Freight Analysis Framework 4 (FAF4)	To obtain total flows by KTons and value between states of select O-D pairs.
2. Surface Transportation Board's URCS	To calculate the shipping cost using rail mode for different commodity groups.
3. Association of American Railroads (AAR)	To obtain the track miles operated for rails. Used as an input for assumption of market share.

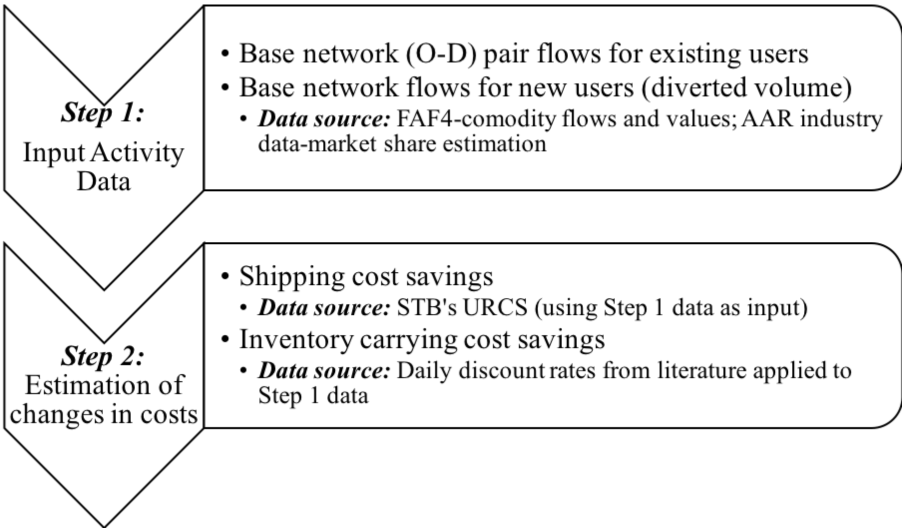

Fig. 2. Model steps and associated data sources.

1) Freight Analysis Framework version 4 (FAF4)-*Data Tabulation Tool*: FAF4 provides freight movement data in tonnage (in thousand tons) and value (in million dollars) between states and metropolitan areas for all modes of transportation and in all industrial sectors. The data is available from the year 2012 to 2015 and as forecasts from 2020 up to 2045. For this work, we extracted freight movement data in tonnage and value between the states of Virginia and Illinois/Ohio/Michigan. 2012 was chosen as the base year since the Heartland Corridor project became operational in the year 2010. Rail and truck mode are selected for estimation of freight movement using rail and for the diverted volumes from truck estimations respectively.

2)STB's Uniform Railroad Cost System (URCS): Surface Transportation Board's URCS has a Railroad cost program tool that can be used to extract railroad expenses for specific railroad services (9). URCS has historically been used for analysis of variable cost assessments for regulatory purposes. In this context, we propose the use of URCS also for estimating transport cost involved in rail freight movement. URCS can be used to calculate total variable costs for moving a specific commodity for specific railroads and cost per ton of moving freight for those railroads. (see Table B 1. in Appendix B). URCS can estimate the cost of physical equipment expenses and at the same time the actual cost of moving freight. When we use the URCS cost data, we are able to capture the above two components of transportation cost simultaneously and is an advantage of using it.

3)Association of American Railroad: Association of American Railroads' data center contains U.S. freight railroad industry data for all U.S. states. It includes statistics for every U.S. state's freight railroad industry, with specific information on the number of railroads, miles, employees, and commodity. This data was used as a reference for our work in estimating the market share for Norfolk Southern railroad in the Heartland Corridor link. The number of track miles operated by NS in the U.S. states of Virginia, West Virginia, Ohio and Illinois in the year 2012 was obtained from this source for this work.

3.3 Assumptions and Parameters

The heartland project was intended to improve efficiency by facilitating double-stacked trains carrying freight. The following benefit triggers are associated with the project. Rail intermodal accompanied by double stacking has the potential of reducing total logistics costs—that is, taking into consideration not only transportation costs but also inventory carrying costs—for an increasing array of commodities, particularly over long distances. This is an important consideration in areas of capacity constraints on trucking. These reductions in LC come with the potential to enable more efficient freight movement and add to overall economy's gross domestic product via private sector profitability.

Reduction in transit time: The central corridor therefore removed 200 miles for freight moving the entire route from the Norfolk to Chicago. The distance reductions and the corresponding original routes are presented in Table 3.

Table 3. Distance for the upgraded route vs. original route options.

Norfolk to	New distance via Heartland Corridor (miles)	Original route 1 (miles)	Distance saved (miles)	Original route 2 (miles)	Distance saved (miles)
Chicago	1049	1169	120	1251	202
Columbus	667	967	300	1038	371
Detroit	875	1164	289	1078	203

Throughput/Capacity and cost reductions: The original route was used to transport coal to the Port of Virginia, and the lines could not accommodate double stacking because of height restrictions, as well as the square profile of the conveyance. The clearance through western Virginia and West Virginia accommodated railcars of up to only 19'1" multi-levels. Hence, double stacking was not possible before the clearance project was undertaken.

Transportation savings from the new rail route: The savings will stimulate new demand for rail freight between the Port of Norfolk and the Midwest markets. Hence, benefits will accrue from cost savings to shippers based on a comparative assessment of truck to rail shipping costs.

Forecasts: Public domain data such as Freight Analysis Framework are used. Both the weight and the value of the commodities are extracted from the FAF4 for rail mode. 'Multiple modes and mail' are also chosen to consider any residual intermodal flows that naturally uses multiple modes like truck-rai, water-rail flowing through the O-D pairs. Due to FAF data features, the NS adjusted corridor FAF flows is assumed to reflect existing users. Domestic freight flows between the O-D pairs, as well as export and import flows, are all considered for analysis. The various input parameters used in the analysis is given in Table 4 (Column 2). The last column addresses how the assumptions are

Table 4. Input parameters used for cost savings estimation.

Parameter	Percentage (%)	For risk and uncertainty analysis
Freight flow growth rate (conservative and approximates the compound annual growth rate for the O-D pairs (FAF forecasts)	1.5	Normal random variable `n(1.5,0.5)
FAF truck traffic growth	3	Norman random variable ~n(3, 0.75)
Discount rate	3%	Static
Market Share for Norfolk Southern	60	Uniform random variable~ u(.4, .4)
Allocation of Multiple modes and mail	10	Static

Mode shift elasticity parameter (Source: literature review as included in Vadali et al., 2017; Clark et al., 2005)	0.5	Static. However, the uncertainty is addressed via the two normal random variables partly.

Market Share: We use a market share apportioning process to extract flows specific to Norfolk Southern (NS) in the Heartland Corridor from the aggregate FAF4 flow data. The market share value is based on the miles operated by each of the major Class I railroads in the states of Virginia, West Virginia, Ohio, and Illinois. These total miles operated are obtained from the American Association of Railroads (AAR) fact sheets available for individual states. The estimates of Norfolk Southern track miles operated in the states of Virginia, Ohio, West Virginia and Indiana along the Heartland Corridor is used as a basis to derive the market share for Norfolk Southern which help to proportion the aggregate FAF4 commodity flow specific to the Heartland Corridor. We use a 60 percent market share for Norfolk Southern railroad in the FAF4 flow (in KTons) and value (in millions of dollars) data that is used in various benefit calculations and as a constant for all years of the analysis period. A sample market share adjusted FAF4 flow and value data is presented in Appendix Table A 1. While including the multiple modes and mail commodity type, an additional 10% allocation percentage is applied on top of the 60% market share. We cannot however comment on the intermodal nature of all the shipments. The percentages are reasonable given the current distribution of rail carriers in the region.

Logistics Cost Savings: Using the LC equation from above, only three of four logistic costs components in a benefit cost analysis are relevant for consideration. The transportation economic efficiency (TEE) metrics shown in Table 5 were used to evaluate the changes in the logistics costs. The following quantification metrics for the first-order TEE metrics are discussed in detail in this paper.

(a) Shipping cost savings for existing and new users (from diverted volumes) were estimated.
(b) Inventory carrying cost savings were estimated because of reduced cost for cargo in transit.

Table 5. TEE metrics related to logistical cost savings.

First order Transportation Economic Efficiency (TEE) metrics	Quantification metrics/Approximated by	Data Needs	Public domain data and tools	Valuation
Travel time and operating cost savings for impacted mode (rail in this case): Existing users.	Shipping cost savings, transport cost/unit of distance	Distance (miles), transit time (days), and directional flows by commodity (tonnage-weight and value).	Freight Analysis Framework 4 (FAF4), Network analysis, URCS data from Surface Transportation Board, AAR.	Commodity specific logistical shipper cost savings (including fuel, loss and damage, crew costs) less inventory costs developed from URCS. Inventory carrying costs savings.
Travel time savings: New users (pricing efficiencies).	Diverted volumes (from trucks to rail), Shipping cost savings for diverted volumes. Transport cost savings/unit of distance	Directional truck flows diverted by corridor segment.	FAF4, Truck-rail modal elasticity, Trucking rates.	Cost savings from diversion-difference in trucking rates over rail.

(a) Shipping cost savings

Two scenarios of shipping cost savings are considered in this work. First, the direct savings attributable to the reduced distance and benefits the existing shippers in the Mid-Atlantic and Mid-West states are included. Second, due to the new user base (shippers), i.e., from the diversion of long haul truck volumes to rail are included. When the freight rail project improves capacity for a capacity-constrained rail system or link, it can result in diversion from truck to rail and related benefits. The shippers who divert from truck to rail would benefit from cost efficiencies in shipping via rail. The formula in Equation (3) is used to estimate the shipping cost savings for each of the commodity type. Total savings are obtained by summing all of the commodity type values.

Shipping Cost Savings (\$) = Savings (in \$ per ton) x Total Flow (in KTons) x 1000 (3)

3.4 Results from application to the case study

An assessment of the impacted area was done using FAF4 data by identifying three O-D pairs applicable to the project for freight movement. They include Norfolk-Chicago (and vice versa), Norfolk-Columbus (and vice versa), and Norfolk-Detroit (and vice versa). A project lifetime of 35 years is considered from the year 2010 when it became operational. The analysis period we have considered is starting from 2012 to 2045 due to the availability of the FAF4 data from 2012. Year 2012 is used as the base year for all analysis. Prepared foodstuffs (45.73 Ktons), Coal (48.63 Ktons), Fertilizer (83.57 Ktons), and Transportation Equipment (108.09 Ktons) are some of the high volume commodity types in the Norfolk-Chicago O-D pair. Appendix Figure A 1. shows the distribution of commodity flow for all three o-D pairs in the Heartland Corridor. From the Fig. A 1., we can infer that bulk goods are the main movement in the Heartland rail corridor, meaning they are less reliable and can have an effect on perishability in turn as in the case of prepared foodstuffs and milled grains. The new and improved Heartland Corridor route can help improve the safety, reliability and perishability impacts of the goods traveling due to the reduced distance and enhanced capacity.

Modal Diversion: The introduction of intermodal efficiencies via double stacking and intermodal terminals provided the potential to create new rail demand from products previously shipped by truck for each of the O-D pairs. Truck flows (in KTons) are obtained from the FAF4 for the year 2012 for the Virginia-Illinois O-D pair (see Table 6). We use a hybrid approach to estimate modal diversion by combining mode choice elasticity (0.5 as a conservative estimate) and the list of divertible commodities. The method is applied to the FAF4 truck volumes for the O-D pair considered and valued by using the difference between a conservative truck shipping rate per ton-mile and the rail costs per ton-mile. Costs savings per ton per mile for rail over truck for each year are estimated by using a conservative truckload shipping rate of \$0.146 per ton per mile (obtained from a recent GAO 2015 report) compared to rail cost per ton mile (see Table 7).

Table 6. Diversion Estimation-potential new users for Norfolk-Chicago O-D pair

SCTG Commodity Type	Mode	Total Flow in 2012 (KTons)	Potential diversion % (from truck to rail)
Cereal grains	Truck	13.17	Significant 40%
Other agricultural products	Truck	10.08	Large 80%
Coal	Truck	0.0006	Small 20%

Table 7. Modal Diversion-Hybrid Approach (Divertible commodities + truck-rail mode choice elasticity + rail cost reduction) for Norfolk-Chicago O-D pair.

Commodity	Cost Savings per ton per mile over Truck	Cost Reduction for Divertible Commodities	Truck Tons Diverted with a Mode Choice Elasticity	Volume Diverted (KTons)

Cereal grain	0.0555	0.0904	14.17%	1.867009512
Agricultural products	0.0727	0.0732	8.72%	0.879768158
Coal	0.0811	0.0648	14..2%	8.52126E-05

Shipping Cost Savings: In this analysis, transit time savings are valued by using a shipping cost estimate, which closely approximates logistical costs to existing rail users. A cost/ton for the new route vs. old route provided the basis for the required calculations. The conventional or typical approach would use time values to value crew time, reliability and damage aspects of assets and/or cargo separately. The Heartland Corridor's double- stacking initiative results in improved capacity and throughput, which in turn results in diversion from truck to rail and related benefits. For instance, the shippers who divert from truck to rail would benefit from cost efficiencies in shipping via rail instead of truck.

The new route reduces the distance between Norfolk and Chicago by 200 miles, and hence reducing the transit time is reduced by 1 day. This reduction is reflected in the savings realized in the shipping costs to existing shippers and customers. There are two types of shipping cost savings: one is directly attributable to the reduced distance and benefits the existing shippers in the Mid-Atlantic and Mid-West states. The second is due to the new user base (shippers), i.e., from the rail intermodal cost efficiencies that lead to diversion of long-haul truck volumes to rail. The analysis period was set from 2012 to 2045, with the base year set to 2012 for the BCA. The variable shipping costs for each commodity category were estimated by using STB's URCS tool. The URCS data was set to base year 2012 dollars. Total flows between the various O-D pairs (Norfolk-Chicago; Norfolk-Columbus; Norfolk-Detroit) were obtained from FAF4 flow data. Using these, the operating costs/ton mile are obtained with the URCS tool. The cost savings were obtained by calculating the difference of cost from old route distance and new route distance, for each of the project's O-D pairs (see Appendix Table B1). These assumptions are used to calculate the shipping cost savings by using the formula in Equation (3). The results obtained are tabulated and presented in Appendix C Table C 1. and Table C 2.

Inventory carrying cost savings: These are calculated using the travel time reduction and the commodity-specific daily discount rates. The savings in cost are calculated for the total value of goods transported for each O-D pair. For the O-D pair, Norfolk-Chicago, the transit time saved (Original route vs. New route) is equal to 1 day. The reduced inventory carrying costs are calculated based on the transit time saved (which is one day in this case), value of cargo developed from the FAF inventory profile, and the daily discount rates (Table 1). A sample of the results for this is shown in Appendix D Table D 1.

The results obtained for the logistics cost savings are computed for the entire project life period. In this case, we consider 25 years of project life period for the Heartland Corridor and the analysis period is hence considered to be from 2012 (year when the freight movement data is available in FAF4 database and just after the year the Heartland Corridor became operational, i.e. 2010) up to 2045. The cost savings computed above are repeated for all the years in the analysis period. A 3% discount rate is used to calculate NPV (net present value). The total savings is computed by estimating the discounted sum obtained in the previous step. The total savings are summarized in Table 8.

Table 8. Cost savings summary table.

Logistics cost savings	Savings (in M$)
Shipping cost savings (existing)	358.05
Shipping cost savings (new user)	146.16
Inventory carrying cost savings	4.75

The savings obtained at the end of the project life time is in the order of million dollars as seen from the figures in Table 8. The total shipping cost savings (adding existing and new user) is $184.39 million. The Heartland Corridor project has resulted in huge savings in terms of shipping and inventory carrying cost to the shippers. The benefits apart from the logistics cost savings for the Heartland Corridor include the external cost savings such as the safety and environmental cost savings, benefiting the public (see Appendix E Table E 1.). This can be compared to the fixed and variable costs incurred for the project for performing a cost benefit analysis (see Appendix E). The project costs in the case of Heartland Corridor are already known (see Appendix E table E 2.). The project costs are typically uncertain for large projects like this but in this case, they are treated as fixed and the focus is on the benefit side since the project is being evaluated expost. The project costs and studies exclude any fixed costs associated with operating equipment itself and this study adjusts that by including a fixed operating cost variable on the cost side which is developed from a comprehensive analysis of R1 statistics of Norfolk Southern. The Present Value (PV) of the project costs and the benefits can be compared to see if the benefits exceed the costs. In the heartland corridor case for the Norfolk-Chicago O-D pair, the Net Present Value was estimated as $89.27 million (see Appendix E table E 3.). Similarly of the other two O-D pairs, the NPV estimated is $2124.66 million for Norfolk-Columbus and $380.16 million for Norfolk-Detroit. As noted in Table 4, we also conducted a Monte Carlo Simulation for the various parameters used in the CBA to account for the risk and uncertainty associated with the various input data and assumptions made for the case study to test the robustness of the NPV. The resulting distribution for NPV after 1000 simulation runs is plotted in Fig. 3. Fig. 4 and Fig. 5 presents similar runs conducted for Norfolk-Columbus and Norfolk-Detroit O-D pairs. In all three O-D pairs, the preliminary analysis suggests a high probability of a successful project with benefits to shippers and carriers.

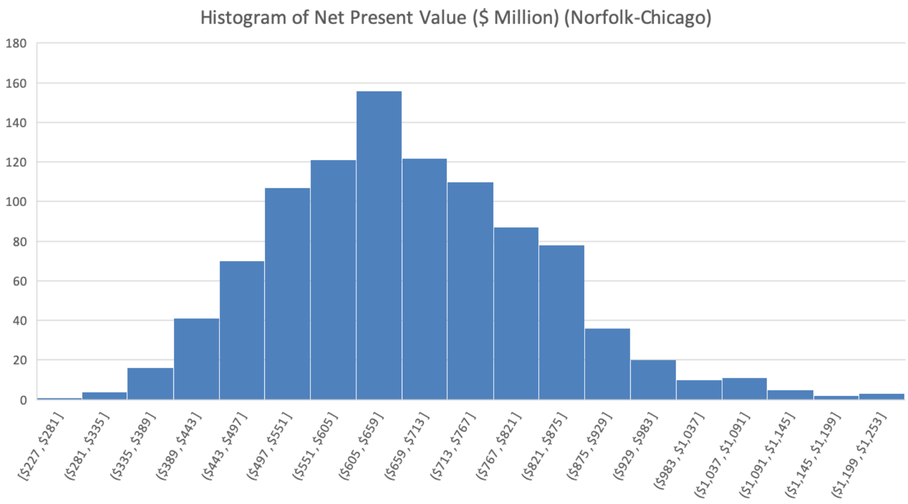

Fig. 3. Monte Carlo Simulation results for Net Present Value of the CBA obtained for Norfolk-Chicago O-D pair

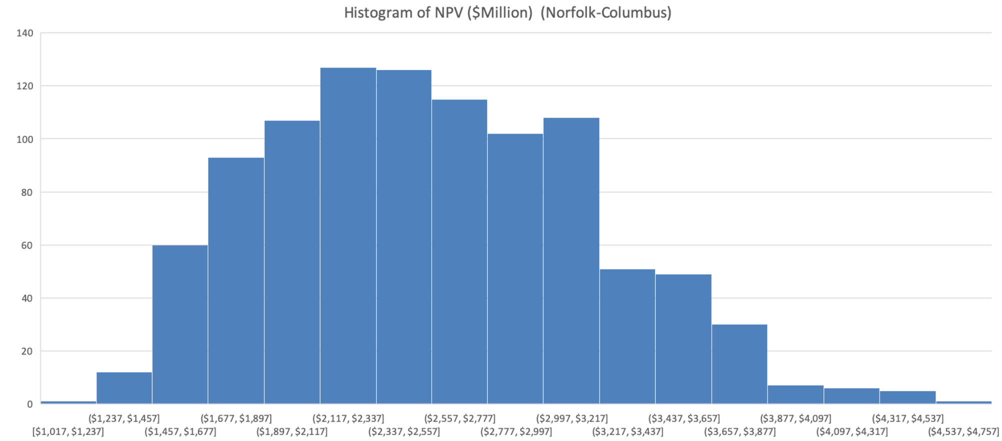

Fig. 4. Monte Carlo Simulation results for Net Present Value of the CBA obtained for Norfolk-Columbus O-D pair

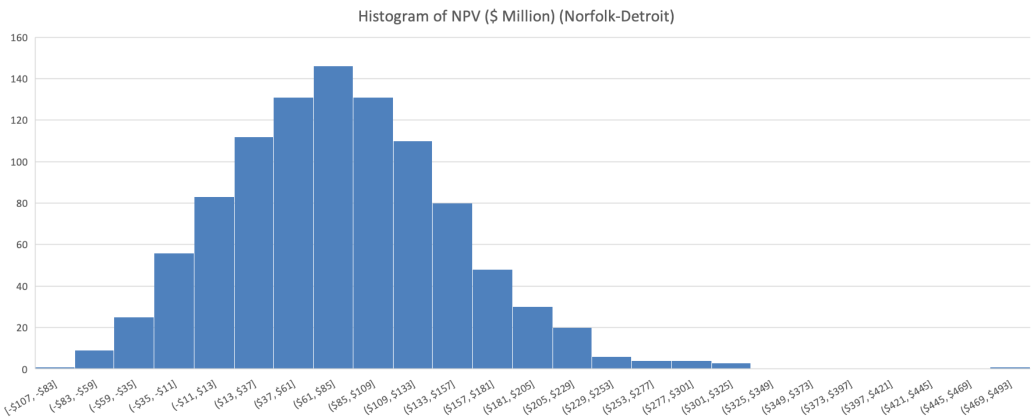

Fig. 5. Monte Carlo Simulation results for Net Present Value of the CBA obtained for Norfolk-Detroit O-D pair

4. Summary and conclusion

In this work, we have departed from the many examples in the literature and have demonstrated the use of an inventory theory approach to logistics cost savings for a freight rail project using public data sources and an approach to estimate modal diversion from trucks to rail for a multijurisdictional case study. The case demonstrated here is for a freight rail project involving multiple stakeholders from multiple jurisdictions and states for the case of Heartland Corridor project, connecting the Port of Norfolk, in Virginia and the Midwest destinations in Columbus, Illinois and Michigan. Freight movement data for truck and rail mode is obtained from Freight Analysis Framework version 4 and used as a basis of input activity data for all the computations in this work. The paper provides the assumptions and steps used in the estimation of the logistical cost savings such as shipping cost savings for existing and new users, and the inventory carrying cost savings. The modal diversion estimation technique proposed in this work can also be used in evaluating various modes other than truck and rail demonstrated in this work by using a similar approach. It is our sincere opinion, that this is the first time such a framework is adopted for preliminary CBA which avoids reliance on static estimates of values of freight time and reliability. We feel the approach is particularly useful for evaluating expansions of existing route networks in a preliminary feasibility analysis. The analysis can be used in cross-border settings or other settings as long as freight flows are available for each O-D pair and operating statistics for rail carriers are available.

The uncertainty involved in the public domain data and the parameters assumed is accounted in this paper by including a Monte Carlo Simulation analysis for the Net Present Value of the project obtained by calculating the aggregate benefits and costs associated. The parameters used in the logistics cost savings estimation such as rail freight growth rate, truck traffic growth rate, and market share were subjected to several simulation runs to find a distribution of the net present value of the project. The use of more accurate rail assignment data for the such projects could result in better results for the analysis, but our aim in this work is to leverage the public domain data and information to produce a reasonable conceptual analysis of logistics cost savings for a multijurisdictional setting as well as to rely on uncertainty analysis in addressing potential scenarios on the NPV.

These cost savings have an important role in evaluating the benefits for a freight transportation project. This method can be adopted for other modes such as road, water or air apart from the rail mode discussed in this work.

Appendix A

Freight Analysis Framework (FAF4) data

Applying the market share of 60% for Norfolk Southern to total flow obtained from FAF4, we get the number shown in Table A 1. In all the tables presented below, only a set of commodity types are included as a sample. While the actual calculations for the savings estimation included about 42 commodity types as per the SCTG classification used in the FAF4 database.

Table A 1. Market share adjusted flow (in KTons).

Origin	Destination	SCTG	Mode	Total KTons in 2012	Total KTons in 2013	Total KTons in 2014	Total KTons in 2015
Virginia	Illinois	Cereal Grains	Multiple modes and mail	0.00054	0.000228	0.000102	0.000102
Virginia	Illinois	Other foodstuffs	Rail	4.79772	5.10408	5.11368	4.86444
Virginia	Illinois	Non-metallic minerals	Rail	0.00018	0.00006	0.00006	0.00006
Virginia	Illinois	Coal	Rail	48.6252	39.93816	40.63062	35.22522
Virginia	Illinois	Gasoline	Rail	0.00006	0	0	0
Virginia	Illinois	Fuel oils	Rail	0.0003	0.0015	0.01878	0.01308
Virginia	Illinois	Logs	Rail	0.00096	0.00012	0.00132	0.0015
Virginia	Illinois	Wood prods.	Rail	0.15594	0.12948	0.0906	0.09276
Virginia	Illinois	Paper articles	Rail	1.48914	1.62174	1.6254	1.55088
Virginia	Illinois	Base metals	Rail	1.78806	1.65156	1.66482	1.72422
Virginia	Illinois	Machinery	Rail	0.22848	0.23688	0.24438	0.24882
Virginia	Illinois	Transport equip.	Rail	107.6388	120.70254	123.17874	126.29088

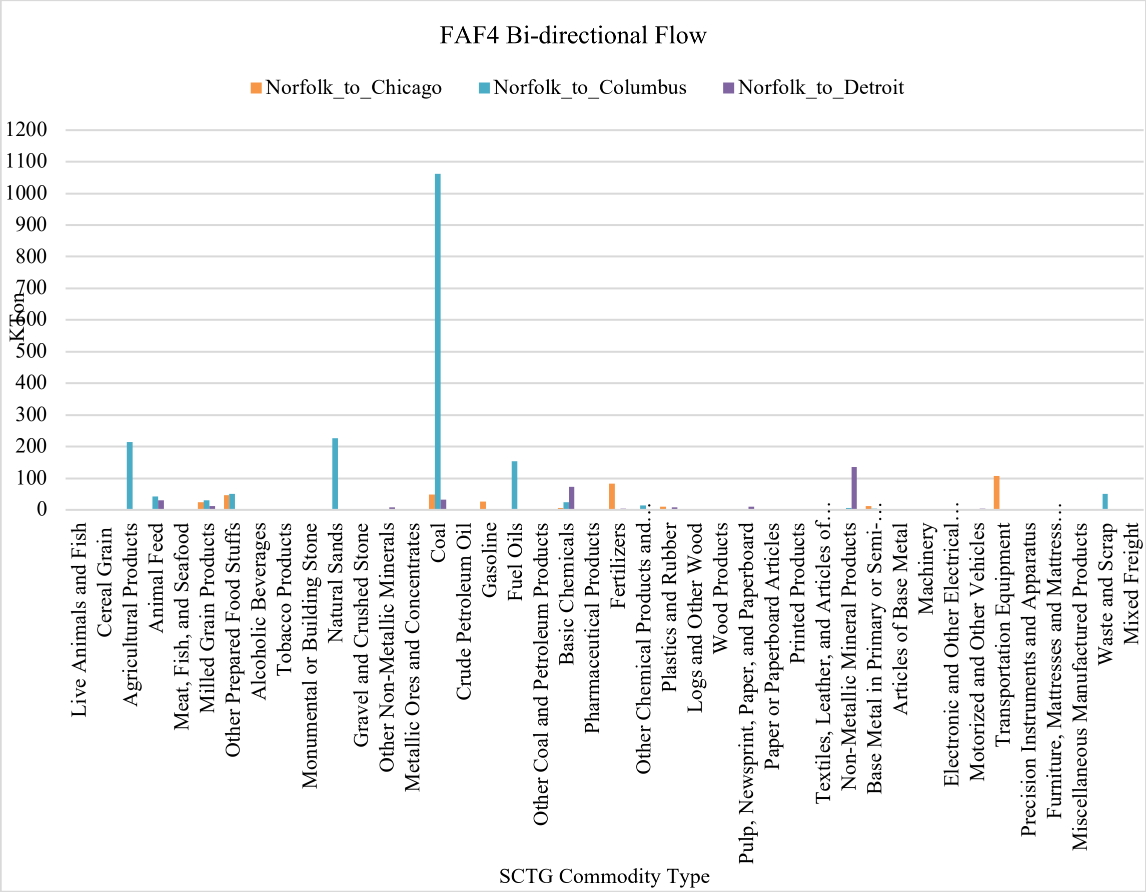

Fig. A 1. FAF4 Bi-Directional Flow Data for Three O-D pairs in the Heartland Corridor.

Appendix B

Uniform Railroad Costing System (URCS) data

Table B 1. URCS Operating Cost Savings Calculation.

SCTG Commodity Type	Cost savings per ton (Year 2012)		
	Norfolk-Chicago	Norfolk-Columbus	Norfolk-Detroit
Live Animals and Fish	0.000	43.607	103.761
Cereal Grain (including seed)	18.265	46.264	68.112
Agricultural Products Except for Animal Feed (other)	14.793	26.609	20.227
Animal Feed and Products of Animal Origin.	14.594	39.793	13.426
Meat, Fish, and Seafood and Their Preparations	23.909	60.847	103.761
Milled Grain Products and Preparations, and Bakery Products	18.265	34.293	12.026
Other Prepared Food Stuffs, and Fats and Oils	15.046	39.749	15.685

Alcoholic Beverages	21.043	0.000	15.432
Tobacco Products	30.611	0.000	0.000
Monumental or Building Stone	0.000	0.000	16.038
Natural Sands	15.44	29.024	0.000
Gravel and Crushed Stone	0.000	33.797	16.038
Other Non-Metallic Minerals	14.462	34.293	13.426
Metallic Ores and Concentrates	16.336	34.282	13.426
Coal	13.106	24.978	11.827

Appendix C

Shipping cost savings calculation

Table C 1. Shipping cost savings (existing user): Norfolk-Chicago O-D Pair.

SCTG Commodity Type	URCS Cost Savings (for year 2012)	Savings (year 2012)	Discounted savings (year 2012)
Live Animals and Fish	0.000	0.00	0.00
Cereal Grain (including seed)	18.265	716.19	716.19
Agricultural Products	14.793	320.86	320.86
Animal Feed and Products of Animal Origin.	14.594	6682.32	6682.32
Meat, Fish, and Seafood	23.909	148.91	148.91
Milled Grain Products and Preparations	18.265	443066.58	443066.58
Other Prepared Food Stuffs, and Fats and Oils	15.046	688968.15	688968.15
Alcoholic Beverages	21.043	2902.58	2902.58
Tobacco Products	30.611	19.65	19.65
Monumental or Building Stone	0.000	0.00	0.00
Natural Sands	17.01	32051.57	32051.57
Gravel and Crushed Stone	0.000	0.00	0.00
Other Non-Metallic Minerals	14.462	1669.54	1669.54
Metallic Ores and Concentrates	16.336	1.47	1.47
Coal	13.106	637375.93	637375.93

Table C 2. Shipping cost savings (new user) using Hybrid Approach to Modal diversion estimation.

SCTG Commodity Type	URCS Cost Savings (for year 2012)	Savings (year 2012)	Discounted savings (year 2012)

Live Animals and Fish	153.154	0.00	0.00
Cereal Grain (including seed)	58.3005	108847.67	108847.67
Agricultural Products	76.3324	67154.84	67154.84
Animal Feed and Products of Animal Origin.	77.3628	341950.89	341950.89
Meat, Fish, and Seafood	28.9915	193411.58	193411.58
Milled Grain Products and Preparations	58.3005	892214.16	892214.16
Other Prepared Food Stuffs, and Fats and Oils	75.0158	1697993.86	1697993.86
Alcoholic Beverages	43.8750	87564.15	87564.15
Tobacco Products	-5.8128	0.00	0.00
Monumental or Building Stone	153.154	0.00	0.00
Natural Sands	64.769	37861.46	37861.46
Gravel and Crushed Stone	153.154	0.00	0.00
Other Non-Metallic Minerals	78.0497	33713.99	33713.99
Metallic Ores and Concentrates	68.3182	4415.19	4415.19
Coal	85.0907	7.25	7.25

Appendix D

Inventory carrying cost savings calculation

Table D 1. Inventory carrying cost savings: Norfolk-Chicago O-D Pair.

SCTG Commodity Type	Daily discount rate	Savings M$ in 2012
Live Animals and Fish	0.11164384	0.0000
Cereal Grain (including seed)	0.05164384	0.0000
Agricultural Products *Except for Animal Feed* (other)	0.11164384	0.0003
Animal Feed and Products of Animal Origin.	0.11164384	0.0002
Meat, Fish, and Seafood and Their Preparations	0.11164384	0.0000
Milled Grain Products and Preparations, and Bakery Products	0.11164384	0.0035
Other Prepared Food Stuffs, and Fats and Oils	0.11164384	0.0104
Alcoholic Beverages	0.11164384	0.0001
Tobacco Products	0.11164384	0.0000
Monumental or Building Stone	0.05164384	0.0000
Natural Sands	0.05164384	0.0000
Gravel and Crushed Stone	0.05164384	0.0000
Other Non-Metallic Minerals	0.05164384	0.0000
Metallic Ores and Concentrates	0.05164384	0.0000
Coal	0.05164384	0.0011

Appendix E

Summary of results from CBA of the case study

Table E 1. Summary of CBA results for Norfolk-Chicago O-D pair.

TEE Metric	Asset Provider	(New) User	Shipper	Public
Shipping cost savings	NA	$146.16 M	$358.05M	NA
Inventory carrying cost savings	NA	NA	$4.75 M	NA
Pavement cost savings	$45.47	NA	NA	NA
Emission Savings	$28.38	NA	NA	$207.53 M
Safety Benefits	NA	NA	NA	$511.14 M
		Total Benefits		$ 1301.49 M

Table E 2. Summary of Heartland Corridor Project Costs

Project Component	Reported Costs (million $)	Base Year Adjusted (million $)
Central Corridor	$191.6 (2010)	$201.74
Commonwelath rail relocation	$60	$63.17
Prichard terminal	$35 (2015)	$33.90
Rickenbacker terminal	$70 (2008)	$74.65
Roanoke terminal	$35 (2010)	-
Fixed operating costs	Using R-1 report values	$181.30
Total Cost		$554.76

Table E 3. Net Present Value Calculation for Norfolk-Chicago O-D pair

Cateogory	Accounting (million $)
PV Benefits	$1301.49
PV Costs	$554.76
NPV	$746.73

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