The National Academies of
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TRANSPORTATION RESEARCH BOARD

Benefit-Cost Methodologies for Evaluating Multimodal Freight Corridor Investments

Thursday, September 7, 2017
2:00pm to 3:30pm ET

The Transportation Research Board has met the standards and requirements of the Registered Continuing Education Providers Program. Credit earned on completion of this program will be reported to RCEP. A certificate of completion will be issued to participants that have registered and attended the entire session. As such, it does not include content that may be deemed or construed to be an approval or endorsement by RCEP.

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REGISTERED CONTINUING EDUCATION PROGRAM

Purpose

Discuss NCFRP Report 38.

Learning Objectives

At the end of this webinar, you will be able to:

- Understand the content and application of the guidebook
- Understand the tools, resources relevant for multimodal benefit-cost analysis, and how to tailor the analysis based on context
- Recognize a project or a solution as a “multimodal” evaluation
- Understand how to treat “difficult to address” issues in benefit-cost analysis

NCFRP Research Report 38: Guide for Conducting Benefit-Cost Analyses of Multimodal, Multijurisdictional Freight Corridor Investments

Join us

- TRB Webinar: **Commodity Flow Survey Microdata to Estimate the Generation of Freight, Freight Trips, and Service Trips**

  Tuesday, September 26, 2017 - 1:00–2:30pm ET

- **Innovations in Freight Data Workshop**

  Spring 2019 in Irvine, CA

Additional Publications Available on this Topic

- TRB’s Transportation Research Record, No. 2609: Freight Systems, Volume 1
- TR News March–April 2017: Innovations in Freight Planning: Trade, Scenarios, and Environmental Justice
- TRB's E-Circular 223: Innovations in Freight Data

You can learn more about these publications by visiting *www.trb.org*

Today’s Speakers

- *Sharada Vadali, Texas A&M Transportation Institute,* What is Multimodal freight corridor BCA?
- *Kenneth Kuhn, Rand Corporation,* Addressing Risk and Uncertainty
- *Anne Goodchild, University of Washington, Seattle,* Heartland Corridor - Freight Rail Investment
- *Elisa Arias, San Diego Association of Governments, Moderator*

WHAT IS MULTIMODAL, MULTIJURISDICTIONAL FREIGHT CORRIDOR INVESTMENT BENEFIT COST ANALYSIS?

NCHRP REPORT 38

GUIDEBOOK- PURPOSE

- **Resource Guide for Multimodal, Multijurisdictional Freight Corridor Benefit Cost Analysis (BCA)**
- **Complement to:**
  - FHWA Economic Analysis Primer
  - FAA Benefit Cost Analysis (BCA)
  - FRA BCA Guidance
  - TIGER BCA Guidance
  - US Army Core of Engineers Economic Guidance Documents
  - OMB Circular A-94
  - ..
- **Gauge public and private benefits, costs from a public sector point of view**

GUIDEBOOK PURPOSE- WHAT IS MULTIMODAL FREIGHT CORRIDOR BCA?

- **Corridors where freight cargo moves or is likely to move using more than one mode.**
  - Infrastructure linkages between modes (highway truck routes, seaports, airports, freight rail, inland waterways).
  - Comparison or evaluation of corridor strategies with potential to influence freight modal shift

- **Corridor strategies with passenger –freight interaction**
- **Multijurisdictional- affected population and jurisdictions**
  - Geographic scale (local, regional, statewide, multi-state)
  - Characterized by freight flows - Terminal investments with multiple entities

WHAT IS IN THE GUIDEBOOK?- STEPWISE FRAMEWORK

- 12 chapters , 11 steps

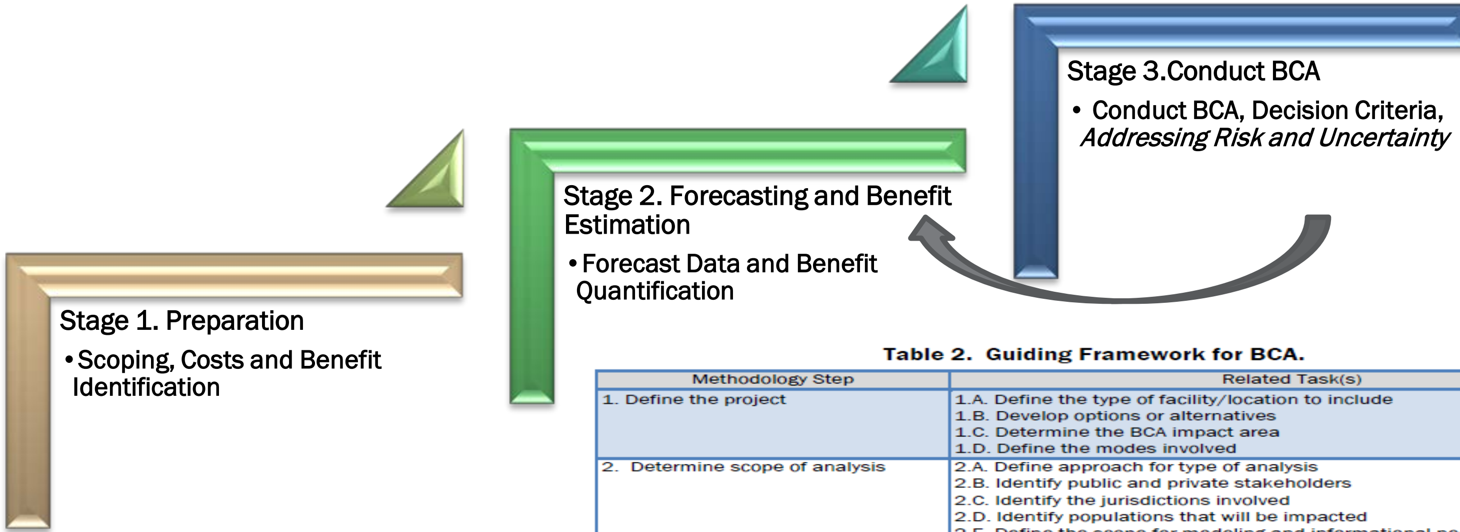


Table 2. Guiding Framework for BCA.

Methodology Step	Related Task(s)
1. Define the project	1.A. Define the type of facility/location to include 1.B. Develop options or alternatives 1.C. Determine the BCA impact area 1.D. Define the modes involved
2. Determine scope of analysis	2.A. Define approach for type of analysis 2.B. Identify public and private stakeholders 2.C. Identify the jurisdictions involved 2.D. Identify populations that will be impacted 2.E. Define the scope for modeling and informational needs 2.F. Determine service life of project(s)
3. Account for project costs	3.A. Identify lifetime costs specific to the project 3.B. Define analysis time frames and determine residual value parameters 3.C. Remove sunk costs 3.D. Adjust costs occurring at different time periods to a base period 3.E. Evaluate funding sources
4. Identify benefit triggers and metrics	4.A. Identify planning objectives to be met 4.B. Identify applicable direct and indirect benefit measures and metrics 4.C. Identify all applicable first-order TEE metrics 4.D. Collect and analyze freight flow data and attributes of major markets
5. Develop forecasts	5.A.Resolve issues related to transport forecasts for project alternatives 5.B. Apply appropriate models and data 5.C. Consider methodological assumptions in using Freight Analysis Framework (FAF), Waybill, Transearch for line-haul networks—rail, waterways, and pipelines 5.D. Determine forecasting volumes and behavioral effects across scenarios and induced demand
6. Quantify and value applicable first-order public and private metrics and information needs	6.A. Quantify and value first-order TEE benefits 6.B. Value other direct metrics 6.C. Identify and access data sources for valuation 6.D. Examine models and sources for performance metrics and valuation measures, and quantify benefits
7. Analyze public externalities and information needs (safety and the environment)	7.A. Quantify externalities 7.B. Select metrics for valuation of externalities 7.C. Review federal funding guidelines for reporting of specific externalities
8. Analyze higher-order quantifiable metrics	8.A. Determine whether WEBs should be considered 8.B. Select WEBs to analyze 8.C. Perform Valuation of WEBs
9. Conduct the BCA	9.A. Determine and apply appropriate discount rates 9.B. Employ best practices for treatment of transfers, tolls, and user charges 9.C. Address equity considerations 9.D. Perform benefit calculations
10 Develop decision criteria and report BCA results	10.A. Develop and employ final decision criteria 10.B. Report BCA results
11. Evaluate and integrate risk and uncertainty	11.A. Identify sources of uncertainty 11.B. Account for uncertainty 11.C. Address optimism bias 11.D. Rerun the BCA and update BCA results

WHAT IS IN THE GUIDEBOOK? (GOVERNING PRINCIPLES)

1. Aggregate benefits net of aggregate costs

2. Incremental approach

3. Choice of discount rates: social opportunity costs &intergenerational

4. Discounting

5. Benefits cover all important perspectives (all freight users, shippers, cargo)

6. Disclosure

7. Transfers

8. Objective framework for decision makers

9. Context sensitive and “useful” information.

10. Transparency on assumptions

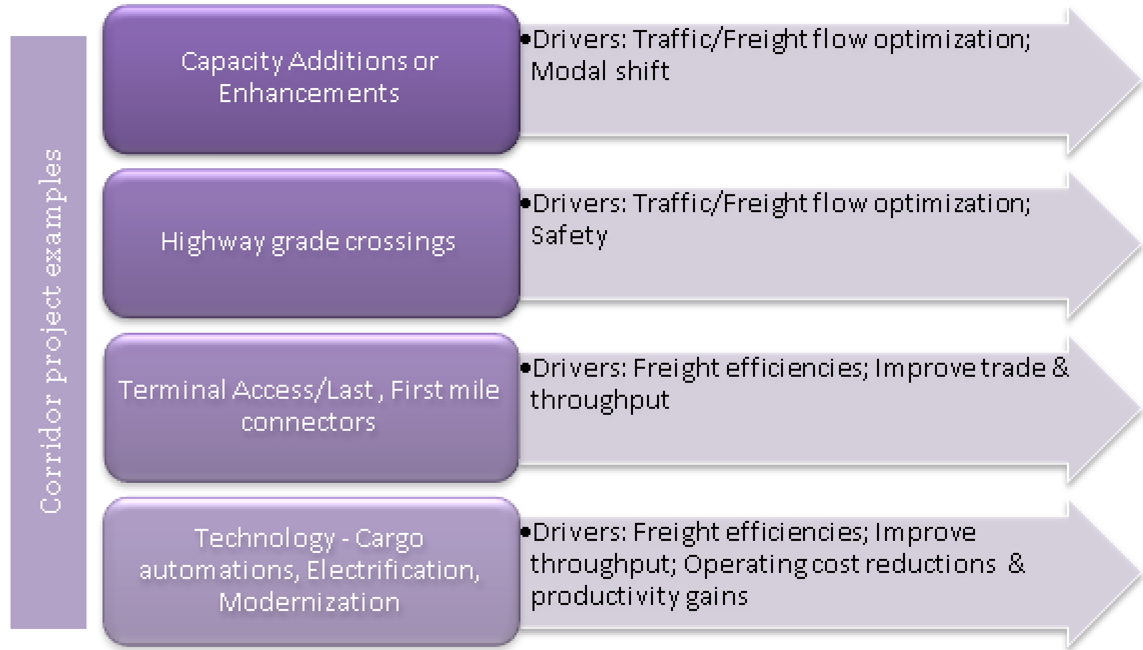
11. Proportionality principle: balance between effort and expected value of information to decision makers

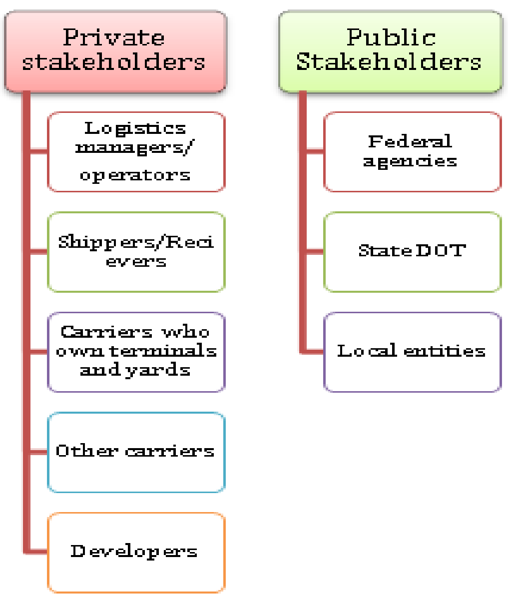
BCA APPLICATION CONTEXTS

- **Planned corridor investments**
  - National Multimodal Freight Network
  - Statewide Freight Plans
  - Statewide and MPO Transportation Improvement Programs
  - Discretionary Grants – FAST ACT
  - Other Grants or Regulatory Requirements
- **Comparison and Vetting of Alternative Modal Strategies**
  - Prioritization
- **Comparison of Alternatives for a Given Project**

STAGE 1: PREPARATION STAGE

- 4 Chapters (Project Definition, Scoping, Costs and Benefit Identification)
- Project definition
  - Modal orientation
  - Single/Group of projects?
  - Mutual exclusion
  - Types of projects
  - Terminal involvement?
  - Develop alternatives
  - Understand the project context & stakeholders

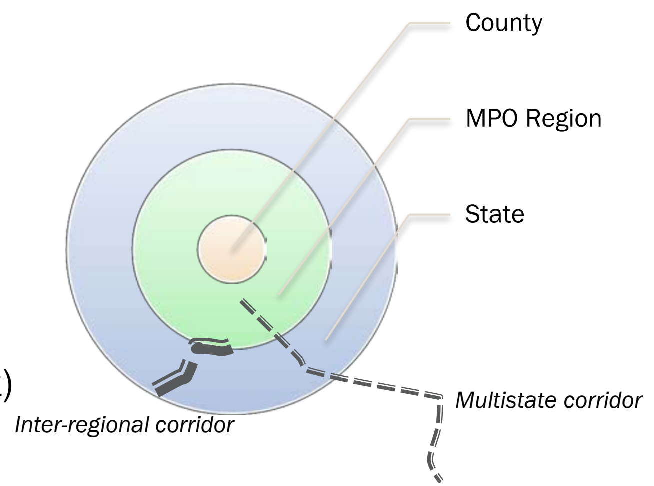




PREPARATION STAGE (CONTD.)

- **Scope of analysis**
  - Geographic scale
  - Jurisdictions impacted
  - BCA impact area
- **Project costs and service life**
  - All categories of lifetime "variable" costs
  - Contingency costs
  - Service life process aspects (to costs and benefits)
- **BCA benefit drivers**
  - " Transportation economic efficiency" (time, cost)
  - Safety
  - Productivity (throughput)
  - Emissions
  - Reliability, frequency
  - Co-benefits: Supply chain efficiencies ; Trade effects- Access to production, resource, or demand markets;
- **Non-BCA Benefit Drivers (e.g. jobs)**

Line Haul Aspect of Freight Corridors



STAGE 2- MULTIMODAL INTEGRATED BENEFIT EVALUATION

- **The guidebook walks you through:**
  - Forecast development for build and nobuild alternatives
  - “Integrated” Evaluation - Reliance on multiple tools related to nature of modal involvement
  - Tools
    - Scale consistent- Regional, state and custom travel demand models or freight models
    - Terminal forecasts
    - Public domain national databases/models (e.g.., Freight Analysis Framework, Surface Transportation Board’s Waybill, Schedule 410 R1, Uniform Rail Costing System, mode-specific tools)
    - Private data sources and models (Transearch, modal specific tools)
    - Forecasting modal demand
  - Default valuation parameters or sources and procedures

STAGE 2- MULTIMODAL INTEGRATED BENEFIT EVALUATION (CONTD.)

- **Forecasting Issues- Data poor contexts (New mode or simply lack of good data).**
  - Lack of freight flows ➔ Build origin-destination profiles (manual or choice models)
  - No formal model ➔ Network analysis; Oakridge National Laboratories Networks
  - How much mode shift to expect ? ➔ choice elasticities and models
  - Consideration of specific "benefits" - "reliability"
- **Addressing land use impacts**
  - Part of forecasting (integrated models)
  - Address as a "risky" factor

Table 9. Direct (First-Order) TEE Metrics and Public and Private Data Sources.

TEE Metric(s)	Quantification Metrics (Same Mode or Diverted Flow) for No-Build and Build Alternatives	Data Needs	Valuation Data Needs	Public-Domain Data and Tools	Private-Domain Tools If Resources Exist and Clearances Obtained	Economic and Shipment Data (Public and Private Domains)
Travel cost (travel time or transport cost) for impacted modes from transport models/network analysis/ simulation models (from Step 4) and/or external data sources (shipper surveys) Also, reliability	• Travel or transit time savings (time saved) • Transport cost per unit of time and/or per ton-mile saved • Delay hours reduction per unit of cargo • Buffer indices (truck freight) • Measures of on-time arrival or measures of lateness	• Speed • Travel time • Distance • Volumes—current and forecasts (e.g., average annual daily traffic, vehicle miles traveled [VMT], units, tons, and carloads) • Directional flows • Peak and off-peak, if needed • Capacity • Vehicle mix • Vehicle occupancy • Commodity flows (O-D matrix) • Commodity mix • Intermodal cargo volumes, if applicable • Global positioning system	• Resource value of time (VOT) (dollars/hour labor time)—USDOT guidance • VOFT per hour or VOFT computed as separate logistical components to degree possible • Market interest rate • Cost metrics per unit of time or distance • Reliability ratio for trucks • Value of freight transport reliability or, if not available, a cost proxy	Conceptual analysis: • Freight Analysis Framework (FAF) flows • FAF routable database • Payload data • Available simulation models by mode • Existing travel demand models, if available, for truck projects[a] • Existing commodity flow models (for cross-modal shifts) • Network analysis • Oakridge National Laboratories routing tools • Mode-specific tools/models/equations to quantify effects. • FAA Terminal Area Forecasts (http://aspm.faa.gov/main/taf.asp) • Railroad performance measures (http://www.railroadpm.org) Feasibility: • Simulation models by mode • Travel demand models • Custom travel models • Public-domain mode-specific tools/models/equations to quantify effects • FAA Terminal Area Forecasts	• Customized models (e.g., CUBE) • Private-domain tools (several) by mode (rail and airports) • Restricted tools from USACE for ports and waterways • Global Insight models • Private-domain mode-specific tools/models/ equations to quantify effects (Table 7) • Association of American Railroads (AAR) models (proprietary Intermodal Competition Model)	Commodity flows and trade data: • BTS/Research and Innovative Technology Administration • STB Public Waybill • U.S. Maritime Administration • U.S. Coast Guard • USACE Waterborne Commerce Statistics • Lock Performance Monitoring System • State departments of transportation (DOT) • Local agencies • Port Import/Export Reporting Service (Journal of Commerce) • USACE Waterborne Commerce Statistics • STB Waybill restricted data sets • Commodity Flow Survey restricted data sets • Global Insight's Transearch • Intermodal Association of North America (IANA)

[a] Some regions and states do not have travel models or commodity flow models. States and regions also vary in the types and models they have available for planning studies.

Highway	Rail	Inland Waterways	Deep-Draft Marine	Air
HERS	RailSim (Systra) more suited for passenger rail	Ohio River Navigation Investment Model (ORNIM) National Economic Development benefits	HarborSym	FAA Airport Airspace Simulation Model (SIMMOD) and Runway Delay Simulation Model
FHWA BCA—HFLRT (useful for corridors)	RTC suited for Class 1 capacity and operational analysis	Other tools with USACE (developed by the Navigation Economic Technologies Program)—Restricted Access	Other tools with USACE (developed by the Navigation Economic Technologies Program)—Restricted Access	Massachusetts Institute of Technology's LMI
AASHTO Redbook	FRA's GTMS suited for rail safety analysis.	USACE has been undertaking efforts to develop system models that allow superior analysis of diversion (induced demand)	USACE has been undertaking efforts to develop system models that allow superior analysis of diversion (induced demand)	Total Airport and Airspace Modeler
STRATBencost (private)	URCS (operating costs) and STB Report R-1 (Tool) only for shipping costs.	Non-USACE projects—P&G Economic Guidance documents 2002 and 2004 (crew costs and operating costs)	Non-USACE projects—P&G Economic Guidance documents 2002 and 2004 (crew costs and operating costs)	FAA Airport Capacity Model
MicroBencost	Individual companies	-	-	FAA Economic Values Guide
Cal-BC Corridor and Cal-BC Network	RAIL//NET	-	-	FAA Airport Delay Model
FHWA *Surface Transportation Efficiency Analysis Model* (STEAM)—multimodal (passenger-truck)	Rail costing models (intermodal costing model) (Owens et al. [44])	-	-	-
Transportation Economic Development Impact System (TREDIS) (private)/MMBCA free. Regional Economic Models-Transight (private). *Note: These include a BCA component that allows multiple modes, but they are not strictly multimodal.*	(TREDIS) (private)/ Regional Economic Models- Transight (private)	Transportation Economic Development Impact System (TREDIS) (private)/MMBCA free.	Transportation Economic Development Impact System (TREDIS) (private)/MMBCA free.	Transportation Economic Development Impact System (TREDIS) (private)/MMBCA free.
Several other tools including in-house tools		-	-	
GradeDec.Net	FRA GradeDec.Net (grade crossings)	-	-	-

STAGE 2- MULTIMODAL INTEGRATED BENEFIT EVALUATION (CONTD.)

- **Freight Benefits must capture benefits to all affected parties**
  - Freight operators, Carriers
  - Shippers/receivers- cargo or industry affects
  - If applicable, impacts on affected entities on other mode (from diversions, passenger/freight interactions)
  - Affected community, if applicable

- **Time (or cost) based freight efficiencies should consider**:
  - Utilization of labor as a resource (carrier perspective) in transit and if applicable, excess time loading/unloading.
  - Utilization of equipment (asset provider, operator perspectives)
  - Value of cargo in transit (shipper perspectives) – the freight "value of time"- (the "passenger" in the freight vehicle)

STAGE 2- MULTIMODAL INTEGRATED BENEFIT EVALUATION (CONTD.)

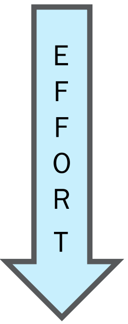
- Total BCA benefits are a sum of "unique" direct (first order) effects, and higher order effects.
  - Difficulties in approximating volume and/or shadow price (valuation measure)
- Geographic scale and/or location interconnectedness → higher order effects.

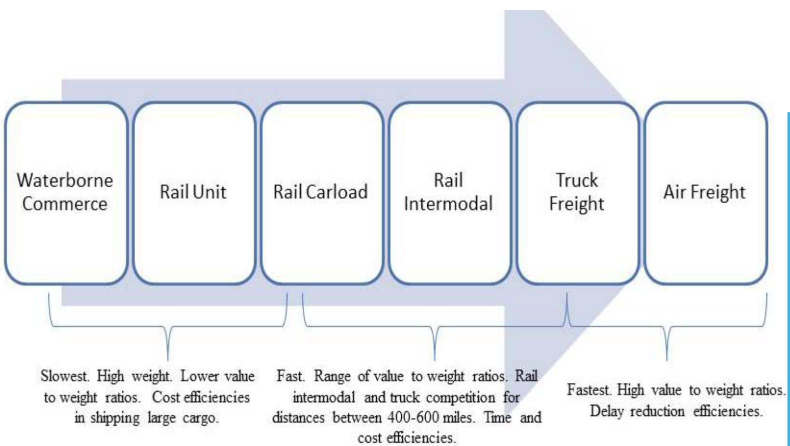
Table 13. Types of Benefits, Timing of Occurrence, and Relation to BCA, EIA, and WEBs.

Temporal Order of Occurrence	Metrics	Temporal Nature and Effects on Firm Output/Productivity of Transport-Using Sectors	Comments	BCA, EIA, or WEB
First-order benefits	Conventional transportation economic efficiency (TEE) metrics: • Change in travel/transit time/transport cost • Change in operating costs including fuel to carriers, operators, and shippers (sometimes included as logistical cost savings) • Travel time reliability Public externalities: • Accident/safety effects • Environmental effects (emissions and air quality)	Short term (immediately following the opening of the project). Assumes firm output (Q) is constant ($\bar{Q}$). No change in O-D volume. Route shifts and diversions.		Conventional BCA.
Second-order benefits (induced, indirect network effects)	• Logistical cost changes leading to reorganization effect • O-D linkages between production and consumption regions	Medium term (3 – 5 years). Firm output (Q) is fixed. O-D volume may change (69).	Applicable in certain circumstances. Of value for intermodal and multimodal movements.	WEB. Hard-to-capture WEBs for all modes.
Third-order benefits (induced)	• Gains from additional reorganization effects such as locational effects and product variability	Longer term (5 – 10 years). Firm output. O-D volume changes.	Occurs in different markets (land and product markets)	WEB. Hardest-to-capture WEBs.
Indirect Effects Not Part of BCA				
Other effects	• Effects that are not considered benefits according to the conventional BCA but can be of interest to policy makers—jobs, regional employment, personal income, and gross regional product	Occur in different markets and at time frames; different from actual investment		EIA and fiscal impact analysis. Supporting analysis.

STAGE 2- MULTIMODAL INTEGRATED DIRECT BENEFIT VALUATION – CHALLENGES

- **Modal consistency in benefits – How does one address “reliability” as a benefit?**
- **Challenge 1 and Solutions: Data unavailable to measure performance adequately on a time-scale**
  - Work with the data you have
  - Consider delay proxies (applicable for all modes)
  - Work with demand model data- requires no-build and build forecast (truck freight)
  - Probe data for establishing performance measures (standard deviations or buffer index) - (truck freight) (For critical supply chain links or projects targeting reliability)





AASHTO Time-Cost Service Spectrum

Example 1 (Specific Benefit Consideration in Guidance): FAA guidance, for instance, is currently among the most comprehensive in its consideration of impacts to shippers and freight delays. It includes three metrics for delay reduction and one for predictability:

- Reduced units of express cargo arriving/departing from the airport after the time required to make the guaranteed delivery time.
- Reduced air freight ton delay hours by airside, landside, and terminal side.
- Reduced truck delay hours in landside access.
- For predictability, a reduced number of aircraft crew required to accommodate posted schedules, which are then quantified in terms of reduced operating costs.

STAGE 2- MULTIMODAL INTEGRATED DIRECT BENEFIT VALUATION-CHALLENGES (CONTD.)

- **Challenge 2 and Solutions: Data may not be available or suitable to value performance in dollars per unit of time/distance.**
  - Update "value of time" using "reliability ratio" (truck freight).
  - Use cargo specific logistics cost approximations per hour of delay or lateness, if available.
  - Use national defaults when available. *NCHRP 7-24 Underway* (truck freight).
  - Conduct study
- **Report BCA with and without "reliability" (for comparisons)**
- **Avoid double counting**
- **Present assumptions**
- **Benefit categories can be different across modes**

STAGE 2- MULTIMODAL INTEGRATED DIRECT BENEFIT VALUATION-EXTERNALITIES

- **External costs can vary based on project and location:**
  - Air pollution effects at the local and regional scale
  - Greenhouse gases at the global scale such as carbon dioxide (CO_2)
  - Noise, water pollution.
  - Accidents/safety (example, grade crossings, highway projects)
  - Health effects induced from air quality.
  - Security implications or risks from hazardous material routing.
  - ..

- **Sketch approaches**
- **Links to specific advanced tools**
- **Default valuation parameters**
- **Resilience building projects emphasize "avoided" losses or costs**

A number of tools can assist the analyst with analyzing public externalities and information needs:

- Appendix F, Table F1, noise social cost values.
- Table 12 and Appendix H for emission factors.
- Railroads and terminals (direct contact).
- EPA Regulatory Support Document (revised 1998) (59).
- EPA Motor Vehicle Emission Simulator (http://www3.epa.gov/otaq/models/moves/).
- EPA marine information (http://www3.epa.gov/otaq/marine.htm).
- EPA 2009 Emission Factors for Locomotives (https://www3.epa.gov/nonroad/locomotv/420f09025.pdf).
- California Air Resources Board (CARB) Emission Factors Model (Truck and Auto Emissions (EMFAC) (http://www.arb.ca.gov/emfac/).
- BLS Consumer Price Index for updating emission cost estimates when using past studies.
- FRA's GradeDec for grade crossings (https://www.fra.dot.gov/Page/P0337).
- EPA's BenMAP for evaluating health effects (based on concentration response functions) (http://www.epa.gov/benmap).
- Integrated assessment models—APEEP (https://sites.google.com/site/nickmullershomepage/home/ap2-apeep-model-2).
- EPA's Co-Benefits Risk Assessment Model (COBRA) (https://www.epa.gov/statelocalclimate/co-benefits-risk-assessment-cobra-screening-model).
- Geographic Information System mapping and aerial imagery.
- FHWA's Traffic Noise Model.
- FAA's Integrated Noise Model.
- Train Energy Model.
- Aviation Environmental Portfolio Management Tool (http://partner.mit.edu).
- FRA guidance and CREATE toolkit (http://www.fra.dot.gov/Page/P0216).
- Guidance on Treatment of the Economic Value of a Statistical Life (VSL) in U.S. Department of Transportation Analyses- 2015 Adjustment (https://www.transportation.gov/sites/dot.gov/files/docs/VSL2015_0.pdf).

More detailed local modeling could use public or private data sources on fleets and

STAGES 1- 2- MULTIMODAL INTEGRATED BENEFIT EVALUATION (KEY POINTS FOR A ROBUST AND TRANSPARENT DATA-DRIVEN PROCESS)

- **Plan analysis effort according to budget and geographic scale**
  - Discussion with planning departments and modelers
  - Jurisdictions impacted by the project
- **Understand the corridor context for project(s)- who is it serving?**
  - Geographic entities
  - Industries and cargo
  - Who else is affected?
- **Leverage available statewide, regional or other models and tools**
- **Acknowledge limitations and make suitable assumptions**
  - Alternatives (build and no-build)
  - Forecasts, analysis period
  - Benefits quality control, residual values
  - Costs quality control (refer to appropriate cost estimating guidance).

STAGE 3- CONDUCTING THE BCA- DISCOUNTING AND EQUITY

- **Discounting (public agency perspectives)**
  - Use rates suggested by agencies (USDOT, FAA, FRA defer to OMB– 7% real for federal funded projects; USACE- nominal rates, and being reevaluated).
  - Intergenerational rates - global environmental benefits- USDOT - 3%.

- **Distributional equity**
  - Jurisdictional (spatial)
  - Public versus private distribution
  - Industry distribution
  - Income level
  - Health effects from air pollution, safety

  (Disaggregation of forecast data to the unit of analysis)

- **Key factors for Considering Equity**
  - Federal requirements- Environmental impact statements, Health impacts
  - Project context/location and purpose and need
  - Magnitude of public and private benefits
  - Benefit distribution across regions and to the broader economy

STAGE 3- CONDUCTING THE BCA –EQUITY

- **Methods**
  - Stakeholder accounting matrices
  - Specific models and tools (e.g.. health
  - Differential values of time
  - Distributional weighting- not recommended
  - USACE perspectives:
    - National and regional benefits
  - Spatial computable general equilibrium models built on causation

Table 18. Example Public-Private Stakeholder Benefit Matrix.

	Stakeholders (General Public, Public Sector, and Private Sector)	Accounting	Total	Impacted Mode 1 (Applicable Users)			Impacted Mode 2
	Benefit categories*			Auto users			
Public user benefits (TEE and externalities) less travel costs	TEE Category	A	A=A1	A_1			
	Travel time						
	Operating costs (including fuel)						
	Reliability, if applicable						
	Travel costs (user charges or tolls)	B (negative)	B=B1	B_1			
	Net public—users/consumer benefits	E = A + B					
				Business work users	Freight shippers	Freight operators	
Private-sector user benefits (TEE) less travel costs, if any	TEE Category	F	F1+F2+F3	F_1	F_2	F_3	
	Travel time						
	Operating costs						
	Reliability, if applicable						
	Logistics effects, if applicable						
	Travel costs, if applicable	G (negative)	G1+G2+g3	G_1	G_2	G_3	
	Net private-sector user benefits	H = F + G					
Affected community/ public externalities				All users/ affected community			
	Safety	I		I_1			
	Environment—emissions and climate change	J		J_1			
Public-sector provider benefits				Asset provider			
	Maintenance, if applicable	K		K_1			
Private-sector provider impacts				Asset provider	Service provider		
	Maintenance, if applicable	L		L_1	L_2		
	NPV of user benefits (TEE) including externalities	M = E + H					
	NPV all benefits (less Residual Values [RVs])[b]	N = M + I + J + K + L					

STAGE 3- CONDUCTING THE BCA –CRITERIA AND ASSESSMENT CONSIDERATIONS

- **BC ratio? NPV? Other criteria?**
  - + NPV is a robust criteria
  - For independent projects and fiscal constraint: NPV first; then consider BCR.
  - For a group of projects that are dependent- and vetting corridor alternatives or strategies- select maximum NPV

- **NPV's must be adjusted for service life differences for cross-modal comparisons. Direct comparisons of BC ratios and NPV s are not appropriate.**
  - Equivalent Annual Net Benefit: NPV is assumed to be a series of equivalent annual payments
  - Common Multiples of Project Duration: use the least common multiple of asset lives

Table B1. EANB of Two Alternative Strategies.

Benefit, Costs Discount Rate 5%	Modal Strategy 1 (Service life 75 years)	Modal Strategy 1 (Service 50 life years)
Discounted cost ($ million)	$7440	$9143
Discounted Benefits ($million)	$9584	$10,638
NPV	$2144	$1496
EANB (NPV)	$111 >	$73

BENEFIT EVALUATION –ADDRESSING OTHER BENEFITS WITH BCA TO DEVELOP A GOOD BUSINESS CASE

- Direct freight efficiencies and clear follow through benefits are part of BCA.
- Use tools effectively to tell a story for large scale projects - Multiple Accounts to address multiple benefit categories including economic impacts on all affected markets.
- Use systematic reporting templates

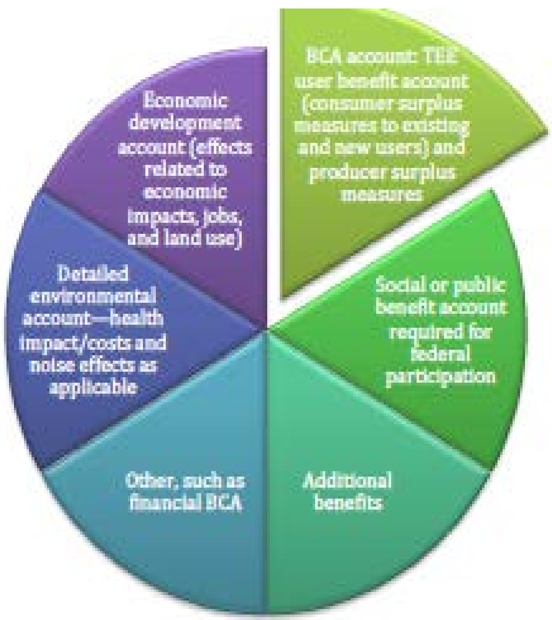


Figure 13. A Multiple Account Evaluation Including BCA for Developing a Business Case

Table 17. BCA Reporting Table—Summary Worksheet (All Quantifiable Metrics).

Benefit Category	Accounting	Market Structure Adjustments, If Applicable
NPV TEE metrics—users (non-business) (less travel costs)	A	
NPV TEE metrics—business users (less travel costs)	B	Adjusted values $B1
NPV TEE metrics—asset providers	C	Adjusted values $C1
NPV tax-related costs, if applicable	D	
NPV asset provider effects—asset maintenance cost	E	
NPV safety	F	
NPV environmental benefits including CO_2	G	
NPV asset provider—revenues	H	
Residual Values	I	
Optional benefits		
NPV reliability	J	
NPV wider benefits as applicable	K	
NPV of costs (including subsidies and net of right-of-way contributions)	L	
NPV benefits (less optional) (1)	M = A + B + C + D + E + F + G + H + I	
NPV (with additional benefits) (2)	N = M + J + K	
BCR (1)	M/L	
BCR (2)	N/L	
Project NPV (1)	M-L	
Project NPV with additional benefits (2)	N-L	

CONCLUSIONS

- Recognize that all estimates involve uncertainty and ask what effect key assumptions, data, and models have on estimates.
- Maintain transparency and objectivity of analytical inputs (data, parameters, growth factors).
- Recognize that BCA evaluation quality varies based on when it is conducted: an early stage "conceptual" BCA is quite different from an advanced planning stage BCA. Investment grade analysis should meet rigorous standards.

ADDRESSING RISK AND UNCERTAINTY

WHERE AND HOW TO ADDRESS UNCERTAINTY

- Benefit-Cost Analysis of Multimodal Multijurisdictional Freight Corridor Investments requires estimation of highly uncertain quantities.

- Techniques for addressing uncertainty:
  - Sensitivity analysis
  - Scenario testing
  - Monte Carlo Simulation
  - Robust Decision Making
  - Etc.

COMMON SOURCES OF UNCERTAINTY

Sources of Benefits-Side Uncertainty	**Sources of Project-Cost Uncertainty**	**Other Sources of Uncertainty**
Population growth rates	Material costs of construction materials	Discount rates
Model forms used in economic growth model	Labor costs during construction activities	Temporal scales of analysis
Parameter values used in economic growth model	Property acquisition costs	Spatial resolution of analysis
Freight traffic growth rate	Construction delays	Optimism bias
Land use changes	Maintenance costs	…
Supply chain structures	Legislative and legal actions	
Energy use	Financial difficulties	
Values of time, including freight values of time	…	
Externality costs		
Accident rates		
…		

WHAT IS SPECIAL ABOUT MULTIMODAL MULTIJURISDICTIONAL, MULTIMODAL FREIGHT PROJECTS?

- **Analysts must forecast:**
  - Freight flows
  - Looking decades into the future
  - Accounting for diversion, if applicable
- **The infrastructure projects are often larger and/or more unique**
- **Obtaining data becomes more problematic**
  - Commercial interests
  - Differences in requirements, data formats across jurisdictional boundaries
- **Diverse reporting requirements, political sensitivities**

IDENTIFY SOURCES OF UNCERTAINTY

- Identify model inputs that are uncertain and likely to impact results.
- Note where sources of uncertainty are used in analysis.
- Describe these sources of uncertainty in a variety of ways that will help you address the uncertainty later.

Source of Uncertainty	Category	Use	Nominal Value / Default Assumption	Rationale	Type of Uncertainty	Exogenous Factor or Policy Variable
Discount Rate	Other (used in estimation of benefits and costs)	Final combination, comparison of benefits and costs	7 %	OMB Circular A-94	Deep uncertainty	Policy variable
Value of Travel Time Savings, Personal Travel	Benefits-side uncertainty	Economic valuation of travel time savings	12.30 (US 2012 $ per hour)	USDOT VOT Guidance 2014	Epistemic uncertainty	Policy variable
Costs of construction materials	Project-cost uncertainty	Estimation of project capital costs	12,300,000 (US 2016 $)	Engineer's notes	Aleatory uncertainty	Exogenous factor
…						

SENSITIVITY AND SCENARIO TESTING

- Sensitivity testing "can make a Benefit-Cost Analysis (BCA) much more informative, can discourage abuse, and can make inadvertent bias more transparent." (Merrifield, 1997).
- Identify realistic ranges for model parameters and realistic scenarios for uncertain assumptions.
- Run separate analyses with optimistic, pessimistic values for each key source of uncertainty.
- Relatively cheap and easy way to demonstrate recognition of role of uncertainty.
- Can be used to combat claims of optimism bias.

EXAMPLE OF AN APPROACH EMPLOYED IN PRACTICE, NOT A PERFECT SENSITIVITY OR SCENARIO ANALYSIS

Table B5: Sensitivity Analysis

	7% Dis-count Rate	3% Discount Rate	Alernative Cost Savings	Alternative Diversion	20 Year Plan-ning Horizon	Break Even Analysis	Federal Funds Leverage
Benefits	$690.2	$1,314.6	$867.8	$1,212.6	$547.8	$376.6	$690.2
Costs	$376.6	$423.2	$376.6	$376.6	$371.5	$376.6	$85.7
B/C Ratio	1.8	3.1	2.3	3.2	1.5	1.0	8.1
Net Present Value	$313.6	$891.4	$491.2	$836.0	$176.3	$0.0	$604.5

Source: National Gateway TIGER Grant Application

MONTE CARLO SIMULATION

- Monte Carlo simulation involves re-running analyses several times after sampling from distribution functions to select uncertain model parameters.
- Recognizes stochastic nature of model inputs, outputs.
- Consider using empirical distribution functions when data are not available.
- Example: gather data on construction costs to develop distribution functions for describing cost uncertainty
- Report 5-number summaries (sample minimum, lower quartile, median, upper quartile, sample maximum) or show histograms of key statistics output by BCA
- Discuss the width of the range of reasonable values. For example compare the lower quartile to the upper quartile of observed values, and relate this to the median.

EXAMPLE OF AN APPROACH EMPLOYED IN PRACTICE

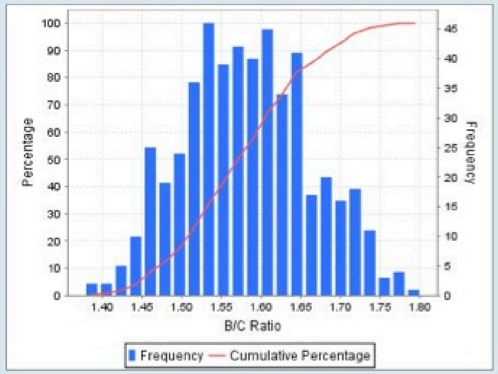
B/C Ratio

2012$

Parameter	Value
Minimum	N/A
Maximum	N/A
Most Likely	N/A
Confidence Level	N/A

Descriptive Stat	Value
Most Likely	1.55
Mean	1.57
Median	1.57
Standard Deviation	0.08
Sample Variance	0.01
Kurtosis	-0.48
Skewness	0.12
Range	0.41
Minimum	1.38
Maximum	1.78
Sum	786.65
Count	500

Percentile	Value
1.00%	1.41
2.50%	1.43
5.00%	1.45
10.00%	1.46
15.00%	1.49
20.00%	1.5
25.00%	1.52
30.00%	1.53
35.00%	1.54
40.00%	1.55
45.00%	1.56
50.00%	1.57
55.00%	1.58
60.00%	1.59
65.00%	1.6
70.00%	1.62
75.00%	1.63
80.00%	1.64
85.00%	1.66
90.00%	1.68
95.00%	1.71
97.50%	1.73
99.00%	1.76

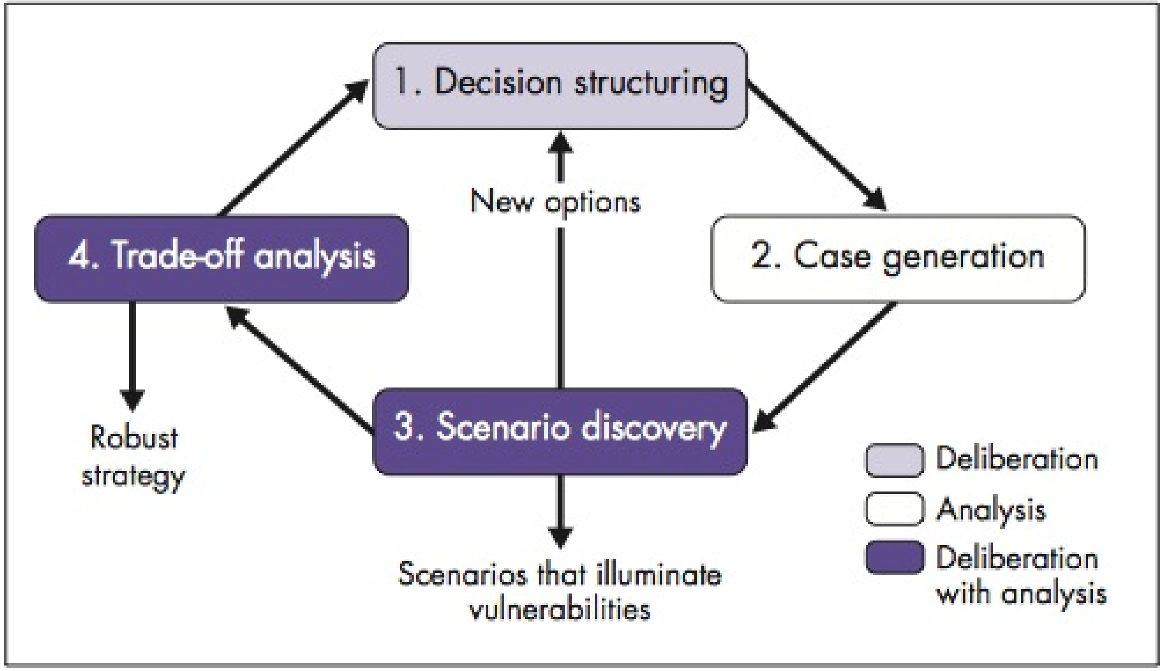


90% Confidence Interval
[1.45, 1.71]
95% Confidence Interval
[1.43, 1.73]
98% Confidence Interval
[1.41, 1.76]

Source: Downeaster Service Optimization TIGER Grant Application

ROBUST DECISION MAKING (RDM)

- Robust Decision Making (RDM) can be used to evaluate sources of uncertainty that cannot be assumed to follow known distribution functions.
- RDM has been applied in climate science, water resource management, etc. but not yet in transportation planning
- Opportunities exist to apply RDM to freight project planning and analysis, particularly for larger projects with complex options for future development, key stakeholders (e.g., ports, railroads), sunk costs, etc.



Source: Lempert et al., 2013

COMMON MISTAKES (1 OF 2)

1. Risk and uncertainty are ignored during analysis. Only single values / point estimates of project benefits and costs are published. This leads to an appearance of false precision. Example: building this intermodal facility at the port will cost $3 and lead to $5 in benefits.
2. Ranges of project costs and benefits are published without reference to how the ranges were found. Example: building this intermodal facility at the port will cost between $1 and $4 and lead to between $4 and $12 in benefits. What methods were used to generate the different estimates of project costs and benefits? What was considered uncertain? What changed during different analyses?
3. Only two or three scenarios were tested. Or only two or three variables and relatively small ranges of parameter values were used when performing sensitivity analysis. Example: scenario testing where discount rates of 3, 5, and 7% were used. This can lead to an underestimation of uncertainty and risk.

COMMON MISTAKES (2 OF 2)

4. Uncertainty in exogenous factors, such as construction costs and freight traffic growth rate, is ignored. This leads to an underestimation of uncertainty and risk.
5. Sensitivity analysis is used to address issues of risk and uncertainty. Each variable, such as population growth rate or freight traffic growth rate, is considered and analyzed separately. Correlations are ignored. Resulting ranges of project costs and benefits can be too narrow to capture true uncertainty and risk. No scenarios that involve adjusting combinations of variables are tested.
6. Sources of deep uncertainty, for example discount rate, are ignored. This can lead to an underestimation of uncertainty and risk. No mention is made of these sources of uncertainty. No scenarios are run where these variables are set to different values.

HEARTLAND CORRIDOR - FREIGHT RAIL INVESTMENT

DR. ANNE GOODCHILD, UNIVERSITY OF WASHINGTON

MOTIVATION FOR A CASE STUDY

- Demonstrate the methodology
- Highlight use of some open access datasets
- Illustrate new techniques
  - Modal diversion
  - Logistics cost saving
  - Handling uncertainty
- Encourage dialogue

THE HEARTLAND CORRIDOR (1 OF 2)

- **Improved railroad freight operations** between the Port of Norfolk and Columbus, Chicago.

- **Public-Private Partnership**:
  - Norfolk Southern Railway
  - Federal Highway Administration
  - Virginia, West Virginia, Ohio

- Involved raising clearances in 28 tunnels and 24 other overhead obstacles.

- Became **operational in 2010**.

THE HEARTLAND CORRIDOR (2 OF 2)

- Direct high capacity rail route allowing double-stacked intermodal trains between peripheral regions in Virginia/West Virginia and Midwest markets.
- New intermodal facilities planned along the central corridor at key locations (Prichard-WV, Roanoke-VA, Rickenbacker Airport-Columbus, OH).
- Reduced distance between Norfolk to Chicago by 200 miles; decreased transit time by 1 day.

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

EXAMPLE ISSUE: DATA SOURCES

- **Freight Analysis Framework (FAF4) provides freight movement data in tonnage and value for different modes and by commodity type for specific years.**
  - Aggregate data; origin and destination are state/zone/metropolitan area specific
  - Basis to develop forecasts for the project lifetime (~25 to 40 years for freight rail)
  - Assumptions in forecasts: constant mode shares.
  - Establish full faith in forecasts

EXAMPLE ISSUE: DATA SOURCES (CONTD.)

- <u>Uniform Railroad Costing System (URCS) from Surface Transportation Board provides variable and total unit cost for U.S. Class I railroads</u>
  - Uses the annual operating expenses and traffic data reported by the railroads
  - Produces reasonable estimates of railroad “variable” cost when all the required input are entered by the user.
  - Uses the annual operating expenses and traffic data reported by Class 1 railroads
  - It produces estimates of railroad “variable” cost when all the required input are entered by the user. These also vary by cargo type. Since, the focus of BCA is on “incremental change” – the estimates are useful.

EXAMPLE ISSUE: ESTIMATING MODAL DIVERSION

- **Method 1: Use market segmentation,** by commodity types and thumb rules:
  - Based on a base set of commodity flows of the "from" and "to" modes (FAF) along with their units by O-D pair.
  - Demonstrate the suitability of the target market or O-D pair for diversion.
  - Develop commodity category filters to identify divertible cargo.
  - …

- **Method 2: Use Modal Switch Elasticities,** rail-truck or truck-rail:
  - Based on cross elasticities (Guidebook)
  - Commodity specific elasticities are results of previous mode choice studies
  - Suggests a maximum diversion opportunity
  - …
- **Method uses a hybrid proposed in the Guidebook combining methods 1&2.**

EXAMPLE ISSUE: BENEFITS CONSIDERED

- The following transportation economic efficiency (TEE) metrics available in the guidebook were used to evaluate the changes in the logistics costs
  - Travel time savings to existing users
  - Shipping cost savings to new users (diverted **volume)**

- ***Cost*** *savings* for both existing and new users (from diverted volumes) were estimated using the formula below
  - *Total Savings= Savings ($/ton)*Total flow (KTons)*1000*

- ***Inventory cost*** *savings* were estimated as a result of reduced cost for cargo in transit is estimated using the formula below
  - *Reductions in Inventory Costs = Commodity value (in $)*Daily discount rate* Transit time saved*

EXAMPLE ISSUE: RISK IN BENEFITS

- The data sources discussed above are public and provide information only at an aggregate level like the total flow of commodity from one state (origin-destination pair) to other for one single mode (truck, rail, etc.).
- Some of the issues associated with the benefit calculations could be accuracy as discussed below.
- A market share apportioning technique is used to estimate the actual commodity flow using the Heartland Corridor rail link between the states impacted.
  - Using the information of miles operated by Class I railroads (Association of American Railroads), we derived a 60% market share and applied it to the Freight Analysis Framework flow data to be used in all of our benefit calculations.

REPORT

http://www.trb.org/Publications/Blurbs/175606.aspx

Questions?

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