CAMBRIDGE SYSTEMATICS

Freight Economic Analysis Tool (FEAT) Development

Methodology Technical Memo

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ITTS

prepared by

Cambridge Systematics, Inc.

report

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1.0 Introduction

Transportation is a critical element of success for regions competing in today's global economy. Public and private leaders seek to invest in transportation systems that will ensure each region's success in global markets. In addition, decision-makers seek clear, rigorous, and timely analysis of how much economic benefit will be generated from competing infrastructure investments.

Several off-the-shelf economic modeling software packages focused on transportation currently are available, including REMI TranSight. However, as many state departments of transportation (DOT) has discovered, while these tools are powerful analytic tools, they lack the ability to assess the full range of freight transportation projects considered by state DOTs without additional front-end processes to develop the inputs required by the economic model.

The International Trade and Transportation Institute (ITTS), on behalf of its member states, commissioned the development of a tool to supplement the economic models currently being used. The Freight Economic Analysis Tool (FEAT) will fill a gap by: 1) providing a transparent tool to process travel model data and prepare inputs necessary to run REMI and IMPLAN economic models and 2) developing sketch planning tools to analyze projects whose evaluation is not conducive to travel demand modeling such as operational highway improvements and freight rail investment.

This report provides details on the methodology used to develop the FEAT Economic Tool which is the tool used to evaluate capacity and other projects using output from a travel demand model (Section 2) and for operational improvements aimed at reducing congestion and improving safety (Section 3). An overview of the methodology for evaluating rail investments is provided in Section 4. A more detailed approach and literature review is provided in the FEAT Rail Tool User Guide. Finally section 5 discusses the operationalization of the methodology for the tool development.

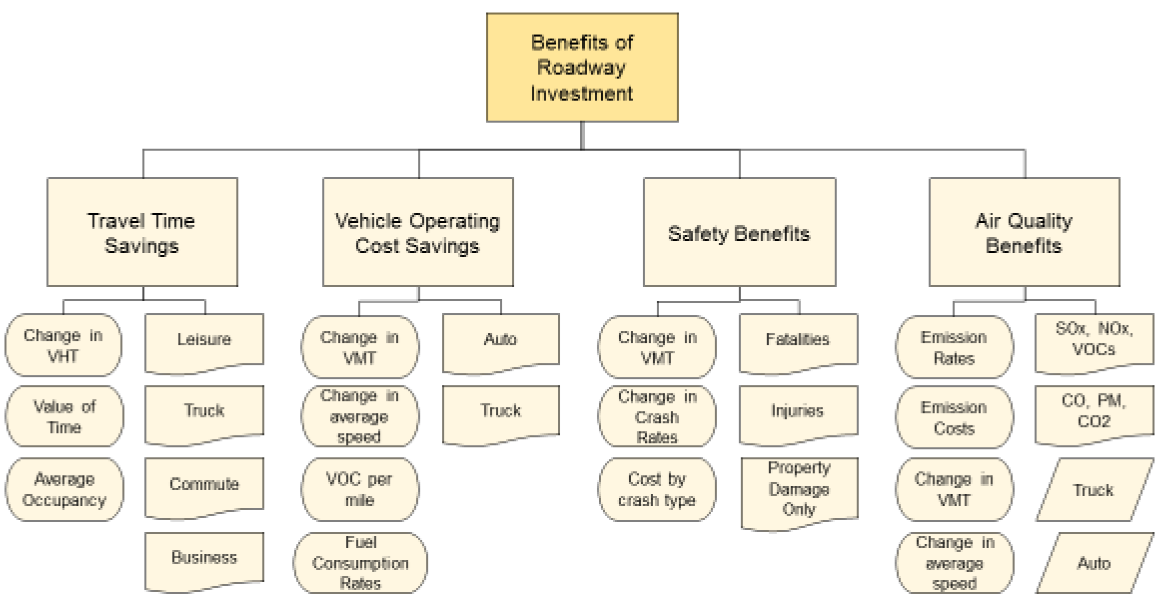
2.0 Roadway Capacity Project Benefits

In current practice, travel efficiencies are the largest share of estimated roadway investment benefits. These efficiencies may arise from travel time savings and vehicle operating costs savings, as well as road safety and air quality improvements. The benefits accrue to users of the transportation system, such as vehicle owners, motorists, or other passengers, but they can also accrue to local communities as a result of a project's contribution to air quality improvement, for example.

Different roadway improvements may lead to different benefit categories that account for the largest amount of accrued benefits. For example, roadway capacity enhancements have the largest impacts on travel time savings, while operational enhancements lead to vehicle operating cost savings and road safety improvements.

Figure 2.1 shows a schematic representation of roadway investment benefits. For each category, the data or assumptions required for the benefit estimation is shown in the rounded rectangles (for example, value of time) and the types included in each benefit category (for example, types of travel or types of vehicle) are shown in document boxes. Each of the benefit categories are discussed below. Specific data sets used are discussed in Section 5.

Figure 2.1 Benefits of Roadway Capacity Investment



2.1 Travel Time Savings

Travel time savings can arise from reduced traffic congestion as a result of a capacity increase, or reduced vehicle delay as a result of newly a built overpass, for example. Travel time cost is equivalent to the opportunity cost of time for passenger trips (either commute or non-work trips), or to the out-of-pocket costs for truck trips or business passenger trips, and are calculated as a function of total vehicle hours traveled for both the baseline and build scenarios (as part of the demand model output). It is important to highlight that travel time savings can be accrued not only by current roadway users, but also by users who divert trips from alternative routes which are no longer preferred after the roadway investment.

Equation (1) below shows daily travel time savings calculations for each type of travel (commute, passenger business, leisure and truck travel) and for each time period (peak and off-peak). In short, the equation uses the value of time, the average vehicle occupancy, and the total amount of travel hours saved (as estimated by the travel demand model) to calculate the total value of travel time savings for each type of trip in each period. Summing across periods we obtain daily travel time cost changes, and summing across trip type we obtain savings for all roadway users.

$$\Delta \boldsymbol{TTC}^{\boldsymbol{TType,Time}} = \boldsymbol{VOT}^{\boldsymbol{TType}} \times (\Delta \boldsymbol{VHT}^{\boldsymbol{TType,Time}}) \times \boldsymbol{Occ}^{\boldsymbol{TType,Time}} \quad (1)$$

Where:

ΔTTC = Change in Travel Time Costs;
VOT = Average Value of Time [$/hr] for the study region by trip type;
ΔVHT = Change in vehicle hours traveled between Build and No-Build for each time period (Build minus No-Build);
Occ = Average vehicle occupancy;
TType = Trip type {Work, Business (Non home-based work), Truck, Non-work trips}; and
Time = Time Period {Peak and Off-Peak}.

For truck transportation, average vehicle occupancy is assumed to be 1, while for passenger transportation average vehicle occupancy is reported in the travel demand model, or is assumed at 1.2 if no information is available. Travel time savings for commuting or business passenger trips are annualized multiplying by 260 working days (52 weeks), while for truck trips and non-work trips they are annualized multiplying by 365 days. Travel time savings for truck travel are considered to be the gross median hourly wage for truck drivers reported for the region. The hourly value of time for passenger travel is considered to be gross median hourly wage specific to the study region.

In the economic impact model travel time savings attributable to shorter commute times are considered savings in household income, and they are valued at half of the gross median hourly wage. Second, business-related travel time savings are considered cost savings for businesses, and are valued at the total median hourly wage. These business cost savings are distributed across various industries based on each industry's transportation cost per dollar of output. Third, travel time savings for non-work trips are not considered as an input in the economic impact model, since they in general do not generate benefits in monetary terms. Finally, travel time savings for truck travel accrue across firms according to the industry's reliance on freight trucking (based on data from the U.S. Department of Transportation's Transportation Satellite Accounts).

In addition to the value of time, travel time saving can also give rise to additional freight transportation impacts through increased reliability and lower shipping cost. Estimating these types of savings is complicated by the fact that much of the data needed is private and shippers consider it confidential competitive data. Despite the challenges in accurately capturing the benefits arising from shipping and logistics cost savings. USDOT has agreed that it is too significant to ignore. In cases where detailed project data such as truck geospatial data that captures trip origins and destinations as well as travel time combined with disaggregated commodity flow data is available, it is feasible to conduct empirical work to estimate these savings as discussed below.

Changes in inventory costs make up the logistics costs borne by shippers as the result of changes in travel efficiencies. Inventory costs are time sensitive, in that they will increase as the inventory time increases. Carrier turn times will impact the inventory time – if turn times increase, inventory times will increase by the same amount, and if turn times decrease, inventory times will decrease by the same amount. The change in inventory costs can be computed using the following equation.

$$\Delta \boldsymbol{AIC_t} = \boldsymbol{IR^{hr}} \times \boldsymbol{AV_t^i} \times \Delta \boldsymbol{AIT_t} \qquad (2)$$

Where:

ΔAIC_t = the annual change in inventory cost in year t

IR^{hr} = the hourly rate charged for inventory. This rate is often an annual rate, calculated as some percentage of the value of the inventory. In this case the hourly rate is calculated from the annual, using 365 day of 24 hours each.

AV_t^i = the annual value of the time sensitive inventory being shipped via truck, that has an origin and/or destination within the study area during year t

t = subscript indicating the specific intermittent year over the analysis period

ΔAIT_t = the change in inventory time.

$$\Delta \boldsymbol{AIT_t} = \Delta \boldsymbol{VHT_t^{tod}} + \Delta \boldsymbol{ABT_t} \qquad (3)$$

Where:

ΔVHT_t^{tod} = the annual change in vehicle hours traveled by truck with origins and/or destinations within the study area during year t

ΔABT_t is the change in annual buffer time in year t, calculated as

$$\boldsymbol{BI_f} = \boldsymbol{BI_n} \left(\frac{\boldsymbol{Delay_f}}{\boldsymbol{Delay_n}}\right) \qquad (4)$$

Where:

$Delay_n$ = the delay for the study area under in the no-build scenario, before the project.

$Delay_f$ = the delay for the study area under in the full-build out scenario, after the project has been completed.

Given that the purpose of the FEAT tool is to automate as much of the analysis as possible combined with the fact that the data necessary to carry out these calculations are rarely available, an generalized assumption supported by USDOT's *Guideline for Evaluating the Economic Impacts of Freight Investments* was used. It is assumed that logistics cost savings, in average, are equivalent to 15 percent of the value of truck travel time benefits. This assumption was also adopted for the early rounds of Federal grant programs.

2.2 Vehicle Operating Cost Savings

Vehicle operating cost savings are also proportional to change in total travel. These savings originate from (i) a reduction in travel delays (as a result of capacity project, for example), (ii) a decrease in distance traveled (as a result of new routes or from diverting longer trips), or (iii) a reduction in vehicle damage (as a result of improved pavement conditions or pothole repair). Vehicle operating expenses results from vehicle ownership and use, and may be divided between non-fuel related costs and non-fuel related costs. Non-fuel related costs can be calculated as the average cost per mile regardless of speed, and includes maintenance, tires, repairs, and mileage dependent depreciation costs. On the other hand, fuel related costs depends not only on mileage but also on average speed and fuel economy.

The difference in total non-fuel vehicle operating costs between the build and no-build scenario can be estimated with equation (4), using the changes in total vehicle miles traveled (from the demand model output) and the average non-fuel vehicle operating costs for each vehicle type (auto and truck).

$$\Delta \boldsymbol{VOC}^{\boldsymbol{VType}}_{\boldsymbol{Non-Fuel}} = \Delta \boldsymbol{VMT}^{\boldsymbol{VType}} \times \boldsymbol{NonFuelCost}^{\boldsymbol{VType}} \qquad (5)$$

Where:

ΔVOC = Change in non-fuel vehicle operating costs;
NonFuelCost = Non-fuel vehicle operating cost per vehicle mile traveled by vehicle type;
ΔVMT = Change in vehicle miles traveled between build and no-build scenarios; and
Vtype = Vehicle type: {auto, truck}.

In a similar calculation, change in fuel vehicle operating costs relies on the reduction in vehicle miles traveled, and on the average fuel economy by type of vehicle (auto or truck) at the current speed, as shown in equation (6)

$$\Delta \boldsymbol{VOC}^{\boldsymbol{VType}}_{\boldsymbol{Fuel,\Delta VMT}} = \boldsymbol{FCR}^{\boldsymbol{Vtype}} \times \Delta \boldsymbol{VMT}^{\boldsymbol{VType}} \times \boldsymbol{FuelCost}^{\boldsymbol{VType}} \qquad (6)$$

$\Delta VOC_{Fuel,\Delta VMT}$ = Change in fuel vehicle operating costs from a change in VMT;
FCR = Fuel consumption rate (gallon per mile) in the build scenario;
ΔVMT = Change in vehicle miles traveled between build and no-build scenarios;
FuelCost = Cost of a gallon of fuel; and
Vtype = Vehicle type: {auto, truck}.

Another factor affecting vehicle operating cost is the relationship between average speeds and fuel consumption. If a project improves average travel speeds from a very poor level of service, users will benefit from reduced fuel consumption even though vehicle miles traveled may remain constant. Equation (3) below shows this relationship:

$$\Delta \boldsymbol{VOC}^{\boldsymbol{VType}}_{\boldsymbol{Fuel,\Delta FCR}} = \Delta \boldsymbol{FCR}^{\boldsymbol{VType}} \times \boldsymbol{VMT}^{\boldsymbol{VType}} \boldsymbol{xFuelCost}^{\boldsymbol{VType}} \qquad (7)$$

Where:

$\Delta VOC_{Fuel,\Delta FCR}$= Change in fuel costs from a change in average speed*;*
ΔFCR = Change in fuel consumption rate (gallon per mile);
VMT = Vehicle miles traveled in the no-build scenario;
FuelCost = Cost of a gallon of fuel; and

Vtype = Vehicle type: {auto, truck}.

The relationship between fuel consumption and average speeds is calculated using average auto or truck fuel economy, and the efficiency curve (consumption-by-speed) is obtained from models developed for assessing such relationship. Annual change in total vehicle operating costs for autos and trucks was estimated as the product of the daily change in vehicle operating cost and 365 days.

2.3 Safety Benefits

In cost benefit analysis, road safety benefits can be calculated as a function of crash rates, crash severity, and vehicle exposure to traffic. First, safety benefits may accrue as an externality created by a reduction in vehicle miles traveled due to shorter trips or trip diversion, and the rationale for this is that the lower the vehicle exposure, the lower the probability of road accidents, given a constant crash rate. The method to assess external safety benefits involves applying the local or regional fatality, injury and property damage only (PDO) rates to the annual changes in vehicle miles traveled, and then, estimating the dollar value by using the comprehensive cost of motor vehicle crashes by injury level, as follows:

$$\Delta \boldsymbol{SC}_{\boldsymbol{External}}^{\boldsymbol{Ctype}} = \boldsymbol{CR}^{\boldsymbol{Ctype}} \times \Delta \boldsymbol{VMT}_{\boldsymbol{t}} \times \boldsymbol{Val}^{\boldsymbol{Ctype}} \qquad (8)$$

Where:

$\Delta SC_{External}^{Ctype}$ = Change in External Safety Costs;
CR = Crash rate by crash type;
ΔVMT= Change in vehicle miles traveled between build and no-build scenarios;
Val = Average value of crash by crash type; and
Ctype = {Crash with Fatalities and property damage, Crash with Injuries and property damage, Crash with Property Damage Only}.

Second, safety benefits can also accrue to projects that directly reduce crash rates. For example, projects that address specific safety concerns, such as improving pavement conditions (therefore lowering the probability of accidents in a specific roadway segment), eliminating rail crossings (therefore lowering vehicle/train crash rates to zero), or adding additional lanes in two lane roads (and reducing the probability of head-on collisions) have direct safety benefits that accrue on top of the safety externalities related to traffic exposure. In order to calculate these benefits, the expected change in the before and after crash rates is necessary, and the benefits are given by:

$$\Delta \boldsymbol{SC}_{\boldsymbol{CrashRate}}^{\boldsymbol{Ctype}} = \Delta \boldsymbol{CR}^{\boldsymbol{Ctype}} \times \boldsymbol{VMT}_{\boldsymbol{t}} \times \boldsymbol{Val}^{\boldsymbol{Ctype}} \qquad (9)$$

Where:

$\Delta SC_{CrashRate}^{Ctype}$ = Change in Safety Costs as a result of a change in crash rate;
Δ*CR* = Change in crash rate by crash type ;
ΔVMT= Vehicle miles traveled;
Val = Average value of crash by crash type; and
Ctype = {Crash with Fatalities and property damage, Crash with Injuries and property damage, Crash with Property Damage Only}.

2.4 Air Quality Benefits

Air quality benefits accrue by reducing emissions that affect local or regional air quality such as carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NOx), particular matter (PM), and sulfur dioxide (SOx), in addition to emissions with impacts at a global level, such as carbon dioxide (CO2), which are included in cost benefit analyses that follow federal guidelines. Emissions can be avoided by reducing total vehicle miles traveled, hence air quality impacts are estimated as follows:

$$\Delta \boldsymbol{AQC}^{\boldsymbol{Etype,Vtype}} = \boldsymbol{ER}^{\boldsymbol{Etype,Vtype,Speed}} \times \Delta \boldsymbol{VMT}_{\boldsymbol{t}}^{\boldsymbol{Vtype}} \times \boldsymbol{Val}^{\boldsymbol{Etype}} \qquad (10)$$

Where:

ΔAQC = Change in air quality costs;
ER = Emission rate in the build scenario average speed, in grams per mile;
ΔVMT= Change in vehicle miles traveled between build and no-build scenarios;
Val = Value of emissions in dollars per gram, by emission type
Etype = Emission type: {CO, VOCs, NOx, PM, SOx, CO2}
Vtype = Vehicle Type: {Auto, Truck}.

The emission rates by vehicle type (auto or truck) and by emission type are calculated by dividing emission coefficients (emissions per gallon of fuel) and average fuel economy for truck and autos (miles per gallon of fuel at a given average speed). Industry standard parameters are used for this calculation. The dollar cost of emissions is given by federal or state guidance for economic impact analysis.

As discussed in 2.2, when a roadway project improves the roadway level of service, and hence increases average vehicle speed, this leads to savings in fuel consumption for all vehicles. In turn, these savings also represent a reduction on emissions, which can be calculated using equation (8) below.

$$\Delta \boldsymbol{AQC}^{\boldsymbol{Etype,Vtype}} = \Delta \boldsymbol{ER}^{\boldsymbol{Etype,Vtype,Speed}} \times \boldsymbol{VMT}_{\boldsymbol{t}}^{\boldsymbol{Vtype}} \times \boldsymbol{Val}^{\boldsymbol{Etype}} \qquad (11)$$

Where:

ΔAQC = Change in air quality costs;
ΔER = Change in emission rate, grams per mile;
VMT= Vehicle miles traveled in the no-build scenario;
Val = Value of emissions in dollars per gram, by emission type
Etype = Emission type: {CO, VOCs, NOx, PM, SOx, CO2}
Vtype = Vehicle Type: {Auto, Truck}.

Finally, emission mitigation is an important component of a cost benefit analysis. In an economic impact analysis, however, these benefits are not computed as they do not have a job or economic multiplier effect on the regional economy.

3.0 Benefits of Roadway Operational and Safety Improvements

The traditional benefit categories of roadway expansion may also accrue to smaller operational and safety roadway improvements. However, operational projects typically provide capacity expansion or safety improvements at a scale that is not captured by aggregate travel demand models. While travel demand models are validated for a regional analysis, operational projects seek to provide benefits targeted at a more microscopic level. In order to estimate the benefits of operational improvements, a planning-level assessment for operations or safety impacts using limited travel demand information and standard parameters is provided by the FEAT tool.

The operational roadway improvements include:

- Increasing Length of Turn Bay
- Increasing the Turn Radius
- Striping Changes
- Signal Timing/Phasing Changes
- Prohibiting Left-Turn Movements
- Prohibiting On-Street Parking
- Adding Turn Lanes
- Adding a Through Lane
- Adding a Traffic Signal
- Adding a Roundabout
- Interchange Reconstruction (Existing interchange is reconstructed to update design standards and potentially add capacity)
- Innovative Intersection (Continuous flow interchange such as diverging diamond interchanges, etc.)
- Grade Separation
- Bridge Replacement

These operational improvements generate benefits from reduced traffic congestion and improved safety. However, as they do not provide a sizeable change in vehicle miles traveled, benefits from reduced vehicle operating costs and from emission mitigation are not considered relevant in this sketch level analysis. Therefore, the analysis relies on the expected delay reduction and on the expected reduction in local crash rates.

3.1 Operational Only Projects

In the sketch level tool, operational only projects are assumed to generate benefits only from travel time savings. The estimation relies on existing Average Annual Daily Traffic (AADT) information for the base year, rather than on more a detailed travel demand model output. For each project, the type of improvement must be specified, such as adding a turn lane or prohibiting on-street parking, as the expected impact may vary by project category (low, moderate, or high impact).

In the model, total travel time savings are annualized with similar factors than those considered for roadway expansion projects: 260 days for commute and business related travel, and 365 days for non-work and truck travel. In order to forecast traffic count values for future years (in order to perform the benefic cost and economic impact analysis), default traffic growth rates and truck mile percentages are based on the parameters used in statewide travel demand models. Assumptions for traffic growth and percentage of truck travel can also be directly inputted into the FEAT tool.

The reduction in delay per vehicle (in seconds) depends on the initial roadway level of service (LOS). If the user does not directly specify the initial LOS in each project, the tool directly assumes an F level. The LOS specification is important since it determines the original delay per vehicle, according to the table below. Therefore, changing initial conditions will also change initial and final delay per vehicle.

Table 3.1 Delay per vehicle based on roadway level of service

LOS	Range of delay per vehicle (seconds)	Default Assumption
A	<10	0
B	10-20	10
C	20-35	20
D	35-55	35
E	55-80	55
F	>80	80

Vehicle delay reduction depends on the type of project considered. For each project category (with minor, moderate or major impact) total delay is assumed to be reduced by a give percentage, based on average values for the types of projects considered. A minor project, such as an increase in the length of the turn bay is expected to save 15% of total delay in congested hours, a moderate impact project, such as adding turn lanes, is assumed to save 30% of total delay in congested hours, and a major project, such as a continuous flow interchange, is assumed to save 60% of total delay in congested hours. The following table shows the percentage of total travel time savings that can be achieved with each type of project being considered.

Table 3.2 Operational Project Type and Impact Level Assumptions

Project Type	Operational	
	Impact Level	Time Reduction
Increase Length of Turn Bay	Minor	5%
Increase the Turn Radius	Minor	5%
Striping Changes	Minor	5%
Signal Timing/Phasing Changes	Minor	5%
Adding Turn Lanes	Moderate	10%
Adding a Through Lane	Moderate	10%
Add a Traffic Signal	Moderate	10%
Add a Roundabout	Moderate	10%
Bridge Replacement	Moderate	10%
Interchange Reconstruction	Moderate	10%
Innovative Intersection (Continuous Flow Interchange, etc.,)	Major	20%
Grade Separation	Major	20%

The tool also uses the K-factor (planning analysis hour factor) as the parameter that determines peak-to-daily ratio of traffic volume. Once multiplied by the daily traffic count (AADT), it gives an estimation of the traffic volume on an average congested hour of the day. The default value is 0.1, but in more urbanized areas with higher traffic volume the k-factor may drop since peak traffic is spread over longer periods of time. This parameters must be adjusted from the default value to conform to the project being assessed, but it typically ranges from 8% to 10%.

The number of congested hours per day is another important parameter to calculate total travel time savings. It is usually given by the travel demand model, or it can be adjusted for the specificities of each project. It is assumed that travel time saving only accrue during hours with delay.

The default parameters used to estimate total travel time savings are shown in the Table below. Each can be adjusted to better characterize specific projects.

Table 3.3 Default Assumptions for Operational Projects

Parameters	Default Value
No-build LOS	F
Delay per Vehicle	80
K-Factor	10%
Number of Congested Hours/day	4

Using these assumptions, the total changes in travel time are calculated with the following equation:

$$\Delta \boldsymbol{TCC}^{\boldsymbol{TType}} = \boldsymbol{VOT}^{\boldsymbol{TType}} * (\Delta \boldsymbol{AADT}^{\boldsymbol{Ttype}} * \boldsymbol{KFact}) * \boldsymbol{Peak} * \boldsymbol{Delay} \quad (12)$$

Where:

ΔTCC = Travel Cost Changes
VOT= Value of Time, per hour
$\Delta AADT\ x\ KFact$ = Change in traffic volume, per congested hour
$Peak$ = Number of congested hours per day
$Delay$ = Delay per vehicle, in hours
$TType$= Trip type {Work, Business (Non home-based work), Truck, Non-work trips};

The annual changes in travel costs are estimated for autos and trucks, using the specified truck percentage, and the annual factors for mode and type of trips. Similarly to roadway capacity projects, only those benefits that accrue to business travel and to truck travel are transferred in full to the economic impact analysis tool, while benefits for commuting travel are accrued at half the gross median hourly wage of the region where the project will take place. The percentage distribution of auto vehicle miles travelled (VMT) by three purposes (commuting, business, and non-work) is obtained for each region from statewide travel demand model.

3.2 Safety Projects Only

Annual safety benefits are estimated when projects are expected to avoid crashes and reduce accident costs. Three groups of accidents are included in the analysis: fatalities, injuries, and property damage only (PDO). In this planning level analysis, different types of projects are assumed to have different impacts on crash rates, which can be minor, moderate or major. The table below shows the assumptions for crash reduction rates for each type of project considered. The assumptions may be overridden by the tool user when the project's safety impact can be more accurately estimated.

Table 3.4 Safety Project Types and Impact Assumptions

Project Type	Safety	
	Impact Level	Time Reduction
Increase Length of Turn Bay	Minor	5%
Increase the Turn Radius	Minor	5%
Striping Changes	Minor	5%
Signal Timing/Phasing Changes	Minor	5%
Adding Turn Lanes	Minor	5%
Adding a Through Lane	Moderate	10%
Add a Traffic Signal	Moderate	10%
Add a Roundabout	Moderate	10%
Bridge Replacement	Minor	5%
Interchange Reconstruction	Moderate	10%
Innovative Intersection (Continuous Flow Interchange, etc.,)	Major	20%
Grade Separation	Major	50%

Important inputs in the benefit estimation are: accumulated distance (in miles) within the project influence area, and the annual average daily traffic (AADT). Similar to operational projects, existing AADT information in the area of influence is required for the analysis. When multiplied by the accumulated distance in the project influence area, this yields the total daily vehicle miles traveled that are subject to safety improvements. The distance is assumed to be 1 mile, based on the length of typical safety project plus the areas on approach and departure, however, this parameter can also be changed by the user.

Using average crash rates, the total number of accidents can be estimated for the base year. The numbers of crashes, by type, are then multiplied by the average crash costs (also by type) estimate the value of safety benefits. Average crash rates may be overridden by the user if more detailed information for the project location is available.

The following equation is used to estimate safety benefits per crash type and per trip type:

$$\Delta \boldsymbol{SC}^{\boldsymbol{Ctype,TType}} = \Delta \boldsymbol{CR}^{\boldsymbol{Ctype}} * \boldsymbol{AADT}^{\boldsymbol{Ttype}} * \boldsymbol{Distance} * \boldsymbol{Cost}^{\boldsymbol{Ctype}} \qquad (13)$$

$\Delta SC^{CType,Type}$= Change in Safety Costs as a result of a change in crash rate;
ΔCR^{CType} = Change in crash rate by crash type;
$AADT$ = Annual Average Daily Traffic;
$Distance$ = Distance of Project Influence, in miles;
$Cost^{CType}$ = Average cost of crash
$CType$ = {Crash with Fatalities and property damage, Crash with Injuries and property damage, Crash with Property Damage Only}.
$TType$ = {Business, Commute, Leisure, Truck}

The total annual benefit in dollars per year is then calculated using 260 days for commuting and business trips, and 365 days for trucks and leisure trips. Finally, savings in accident costs in 2040 are also estimated based on the default or user specified value of annual growth rate from 2010 to 2040, crash rates by type, crash costs and crash percentage of reduction by project type.

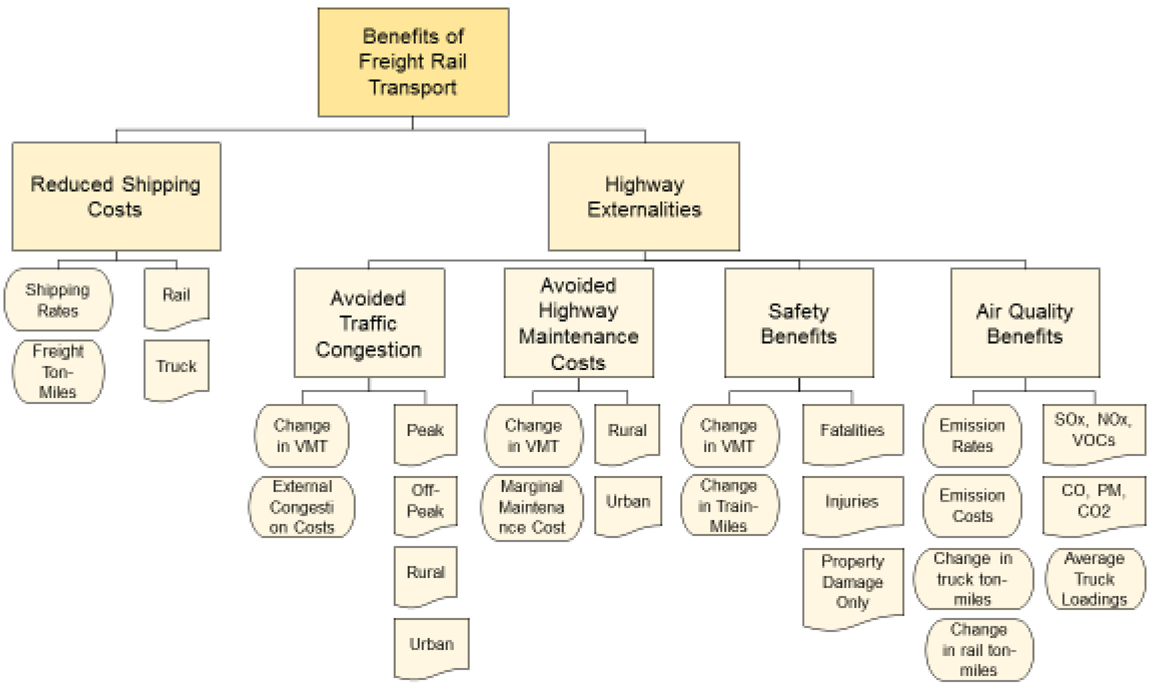
3.3 Operational and Safety Projects

Roadway projects can generate benefits both from an operational perspective (through travel time savings) and from a safety perspective (through crashes avoided). In this case, the user will combine the two previous analysis and estimate the total benefits using the same assumptions and methodology for both benefit categories.

4.0 Railroad Projects

Estimating railroad project benefits involve, for the most part, similar travel efficiency categories as those for roadway investments. However, these benefits arise not only from savings within the railroad system, but also from the interaction between the railroad and roadway systems as a result of the potential for truck-to-rail diversion. Other rail project benefits include shipping cost savings from stronger supply chain networks or from transportation productivity gains. Examples of railroad projects include capacity expansion (which includes new intermodal yards that potential for intermodal freight), track upgrades, at-grade crossing elimination, and double tracking. Figure 4.1 below shows a schematic representation of the potential benefit of rail investment, as well as the data required to estimate each benefit category.

Figure 4.1 Benefits of Freight Rail Transport



4.1 Shipping Cost Savings

Shipping cost savings are internal benefits accrued to shippers. The benefits arise from the diversion of freight from truck to rail, and hence from lower rates on rail relative to truck. Shipping cost savings are a relevant source of efficiency gains, as they lead to an overall cost reduction in the transportation system. Moreover, reduced shipping rates can be measured as benefits from different sources: better productivity of rail vs. truck, or increased access to new markets through lower transportation costs.

In order to quantify shipping benefits as a result of diverted freight from trucks, the net change in total in shipping costs must be assessed. First, this involves estimating the additional number of ton-miles carried by rail. As most travel demand models do not integrate railway and roadway, diverted freight must be estimated by analyzing the potential for truck-to-rail diversion in each region. In the model, this can be either a direct input when freight diversion has been previously estimated for the project, and should be broken down between terms of intermodal units, and boxcars, and other. Otherwise, an estimation of the diversion potential can be calculated using the FEAT tool, which has available freight flow data from the Freight Analysis Framework. Current regional rail mode share is compared to the national rail mode share in order to estimate rail freight potential for each type of commodity. Total truck miles diverted is then calculated using average truck carload for each type of commodity

$$DiversionPotential^{FType} = TotFreight^{Ftype} * (\%NatAvg^{Ftype} - \%Current^{Ftype}) \quad (14)$$

$DiversionPotential^{FType}$ = Diversion potential in tons, by commodity
$TotFreight^{Ftype}$ = Total freight with origin and destination in the region of analysis in tons, by commodity
$\%NatAvg^{Ftype}$ = National rail mode share average, by commodity
$\%Current^{Ftype}$ = Rail mode share in the region of analysis, by commodity

Second, shipping costs are estimated by multiplying additional rail freight with the corresponding difference between average shipping rates for rail and truck. Shipping rates, in this context, reflect the total shipping cost – including drayage costs for intermodal shipping – for the rail mode.

Equation (15) below summarizes the changes in shipping costs:

$$\Delta SC^{FType} = (SR^{Rail} - SR^{Truck}) * (DiversionPotential^{Ftype}) \quad (15)$$

Where:

ΔSC = Change in total shipping cost;
SR = Average Shipping Rates per ton-mile;
$\%Diverted$ = % of truck freight diverted to rail;
$TotalFreight$ = Total annual freight in tons transported in the railway area;
$FType$ = Type of commodity.

4.2 External Benefits of Truck Diversion

Railroad projects also create benefits on the roadway as a result of truck diversion. Truck-to-rail diversion produces positive externalities associated with the reduction of truck miles traveled and truck hours traveled. In this section, as travel demand models do not usually integrate roadway and railway demand, the truck miles traveled diverted must be estimated using the potential diversion for each commodity type, truck load factors, and total freight in tons. The externalities include reduced traffic congestion, reduced roadway wear and tear, improved road safety and better air quality.

4.2.1 Congestion

The rationale behind the impact of truck diversion on road congestion is that fewer vehicles on the road alleviate traffic and generate travel time savings for other road users. In order to quantify this benefit, the amount of vehicle miles traveled by truck that are diverted to rail is estimated using potential diversion by commodity as well as average load factors for each type of commodity. Moreover, the Federal Highway Administration has estimated the external costs of truck driving, which is the delay cost imposed by a truck on other users of the road. The external cost is calculated for peak and off-peak periods, as well as for rural and urban roadways – therefore a weighted average representative of truck miles is calculated. The total savings in external costs related to road congestion can be calculated using the following equation:

$$\Delta CS = CC \times * (\%Diverted^{Ftype} * \frac{TotFreight^{Ftype}}{LoadFactor^{FType}}) \quad (16)$$

Where:

$\Delta CS^{Time,Road}$ = Changes in Congestion Cost ($)
$CC^{Time,Road}$ = External Cost of Congestion caused by truck ($);
$TotalFreight$ = Total annual freight in tons transported in the railway area;
$LoadFactor$ = Average truck load factor in tons;
$FType$ = Type of commodity.

4.2.2 Roadway Wear and Tear

In addition to congestion, truck-to-rail diversion also reduces roadway wear and tear. Compared to autos, trucks cause the most damage on the roads, hence a decrease in truck miles traveled also lowers road maintenance needs. In order to measure total benefits in dollars from avoided physical stress on roadways, the marginal road maintenance expenditure by type of roadway must be assessed (default estimates by the Federal Highway Administration are used). Maintenance costs are assumed to be for the average truck and the average mix of urban and rural roadways. Cost per mile is then multiplied by the estimated total truck miles diverted, as shown in equation (17):

$$\Delta HMC = MHMC \times \left(\%Diverted^{Ftype} * \frac{TotFreight^{Ftype}}{LoadFactor^{FType}}\right) \qquad (17)$$

Where:

ΔHMC^{Road} = Change in Highway Maintenance Cost ($);
$MHMC^{Road}$ = Marginal Highway Maintenance Cost ($/mile);
$TotalFreight$ = Total annual freight in tons transported in the railway area;
$LoadFactor$ = Average truck load factor in tons;
$FType$ = Type of commodity

4.2.3 Safety Externalities

A change in truck miles traveled due to truck-to-rail diversion also generates road safety benefits. This benefit may be calculated in a similar way as the safety benefits shown in 2.3. That is, using specific information on crash rates, the average costs of road accidents (fatalities, injuries, and property damage), as well as estimated reduction in total vehicle miles traveled due to modal shift. If the railway in which the freight will be diverted to also poses safety risks (calculated with historical rail accident rates in the region per train mile), then those are to be included in the net calculation of the total safety benefits.

4.2.4 Air Quality Externalities

In a similar way to safety benefits, air quality benefits also arise from a reduction in truck miles traveled. The dollar value of these benefits is estimated using the same equation as 2.4., thus employing average emission rates for trucks (per mile) as well as the value of the different types of fuel emissions (CO, VOCs, NOx, SOx, PMs, CO2).

These air quality benefits must also be calculated net of equivalent rail emissions, which also requires information on average locomotive emissions by pollutant type. It is important to highlight that while truck emissions are calculated on a per mile basis, locomotive emissions can be approximated on a per ton basis (following guidance by the Environmental Protection Agency), for which a conversion factor must be used such as the average truck load by commodity. Overall, rail transportation is estimated to be 11 times more efficient than truck transportation with respect to carbon dioxide emissions, for example.

4.3 Benefits from Rail Upgrades (up to 286,000 lbs.)

Railway upgrades that allow heavier trains on the tracks have a direct impact on rail cost effectiveness. Heavier loads reduce costs per ton-mile as railroads become more productive, introducing economic efficiency gains to the rail transportation system, and generating benefits in terms of shipping reliability and shipping time. Different types of benefits can be realized from such investments.

First, truck-to-rail diversion is a major source of rail upgrade benefits. Mode change is made possible by new freight rail shipment in industries that prefer rail shipping with higher volumes. A more reliable and faster transit time also make rail a more viable option vis-à-vis truck. Finally, if there are capacity constraints on the railway, truck may be a more reliable option for shippers or there is excess rail demand that cannot be met. Therefore, a more productive rail system reduces logistic costs for shippers that choose the rail mode.

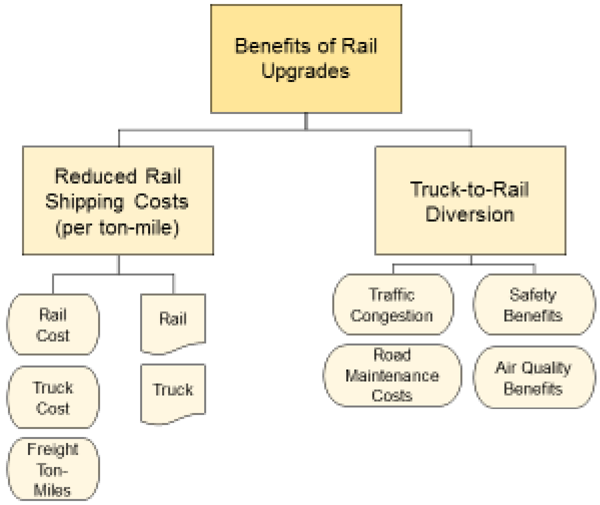
In a similar way than the calculations in 4.1, rail diversion potential can be calculated using the differential between the rail mode shares in the region where the investment is taking place and the national average. In case the project has already estimated the additional freight expected from the upgrade, then it should be used directly as an input into the model. Once the number of truck miles diverted from the roads is calculated, the externalities (alleviation of congestion, safety improvement, roadway wear and tear reduction, and emission mitigation) from reduced truck travel on roadways can be calculated using the equations in 4.2.

Second, shippers also benefit from lower rates on rail compared to truck. The reduction in shipping costs is calculated as the differential between shipping costs per ton-mile for truck and rail (as calculated in 4.1), a reflection of the reduced logistics costs.

Other benefits from rail upgrades that are not calculated in the planning-level tool, but may be relevant for larger investments include: (i) transit time savings, as the new railway may allowed higher average speeds (however, this is only relevant for shipments that travel longer distances over rail), (ii) emission savings per ton-mile for freight that currently uses the railway, and (iii) private benefits for the railroad, which will be able to realize economies of scale.

Figure 4.2 below shoes the potential benefits of rail upgrades and the required data and assumptions to estimate each category.

Figure 4.2 Benefits of Rail Upgrades



4.4 Benefits from Double Tracking

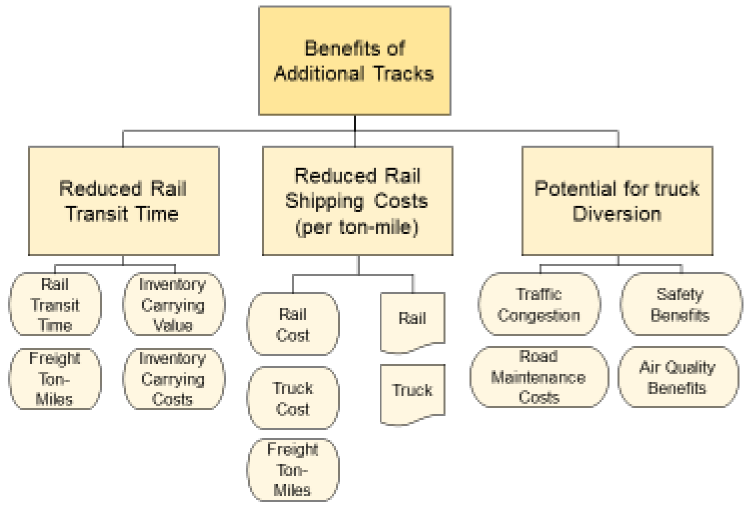
Double tracking generates benefits from the alleviation of capacity constraints by reducing logistics costs to shippers currently using the railway and to roadway users through externalities from the diverted use of less efficient modes.

Since double tracking makes rail ore reliable, efficient and faster, these characteristics reduce the logistics costs for shippers that previously chose truck transportation. The estimation of the potential diversion from truck-to-rail is based on the same methodology used in 4.1, calculating the differential between the rail mode shares for each commodity in the region where the investment takes place with national averages. If the project has already estimated potential diversion, this data can be directly applied in the model. Direct shipping costs can also be calculated as the differential between truck and rail average shipping costs per ton-mile.

In addition, time savings will also accrue to shippers, as double tracking reduces the need to finance inventory while goods are in-transit on rail. Average inventory carrying costs can be estimated based on the number of ton-miles, the average value per ton of freight rail moved, and the estimated average costs of in-transit inventory (as calculated by the Federal Highway Administration).

Private benefits for the railroad are also expected to be accrued, however, these benefits are not included as a public benefit calculation in the model. Cost savings accrue from lower train operating costs of train crews, maintenance, fuel, etc., which are time related and increase with the amount of transit time.

Figure 4.3 Benefits of Double Tracking



5.0 Operationalizing the Methodology

The tool is based on different modules that analyze roadway and railway projects with different characteristics. First, roadway projects that result in changes to capacity network flow are assessed using the output from travel demand models (TDM), for example, statewide or regional travel demand models, such as the ITTS Southern Highway Interactive Freight Traffic (SHIFT) model. Traditional benefit categories, such as travel time savings, road safety improvements, reduction in vehicle operating costs, and air quality benefits are calculated and used as inputs for the economic impact analysis. Smaller operational roadway projects, such as intersection realignments, can be analyzed with a separate planning-level tool that does not require TDM inputs. Moreover, FEAT also recognizes that some projects have an impact on logistics costs, for example, by reducing the buffer times required to ensure timely deliveries (reliability), and the inventory costs associated with freight transit time.

Rail is another planning-level module of the tool, and it includes the assessment of different types of railway projects, such as capacity expansion (including intermodal yards), grade crossing elimination, rail upgrades (railway capacity up to 286,000 lbs.), and double tracking. The tool is based on the benefits from the reduction in shipping costs as a result of a more efficient rail system, and on truck-to-rail diversion, which generates positive externalities on the roadways as a result of fewer truck mileage.

The different FEAT modules allow the calculation of benefits to transportation system users through benefit-cost analysis (BCA) and the calculation of the impact on the economy at large, as a result of the additional income and jobs, using economic impact analysis (EIA). This section describes the data requirements and other external modeling data required to operationalize the data.

5.1 Data Requirements

In order to accurately quantify the benefits and costs of transportation investment, a number of data elements must be incorporated into the model. To ensure the most accurate model results the most recent data sources and locally or regionally specific data should be used, where available. Some of the data inputs to the model are provided by external data sources, such as federal or state agencies. Some of the information, particularly that information related to the specific project(s), must be provided by the model user. Much of the analysis is driven by information taken from a travel demand model, which is used to establish baseline level of traffic activity, and then estimate the changes resulting from some change in the road or rail network.

5.1.1 User Provided Data

The user must provide information specific to the project. If actual values are not yet know, estimates may be used. Using a range of estimates (high and low, for example) can produce a range of results, which may be useful in the context of risk assessment.

a. **Construction Costs –** To conduct a cost benefit analysis, the cost of completing the project must be included. Also, in the short-run, construction spending will boost local employment and spending.

b. **Maintenance and Operations Costs –** The future cost stream necessary for maintaining an acceptable level of service for the improvements, must be included in the costs of the project.

c. **Project Description –** Some attributes of the project must be known. These include, but may not be limited to,

- **Construction Schedule –** A timeline for the construction of the project is needed to understand the timing of the related capital expenditures and economic stimulus. The construction schedule will also set the date from which the project will be complete and its expected benefits will begin.

- **List of Improvements –** A list of the specific improvements included in the project is need in order to make the required changes in the travel demand model, and select to the appropriate benefit categories and model modules.

- **Future Pavement Conditions –** Not all projects will involve changes to pavement conditions, but those that do will have an impact on future congestion levels, user costs, and crash rates.

d. **Study Timeline –** Transportation investment projects create a stream of benefits and costs into the future. The aggregate of these benefits and costs will differ depending on the future time horizon set for the analysis.

e. **Discount Rates –** Based on the idea of “the time-value of money”, future benefits and costs are not as valuable as current benefits and costs. As they move further into the future their current value decreases. The rate at which future benefits and costs are discounted to convert them to current values is the discount rate. Discount rates are used to set return on investment hurdles, and a change in the rate used may make the difference between a positive and negative net present value for a project.

f. **Truck-Rail Diversion Rate –** One of the benefits of investment in freight rail is a more efficient rail system. While the logistics costs of shipping via rail are reduced, some freight that previously had shipped via truck is diverted to rail. FEAT calculates total potential diversion by commodity using commodity-flow data, and assumes that diversion occurs until the rail mode share for a given commodity in the project area reaches the national average. The user may instead use other diversion rate assumptions.

5.1.2 Travel Demand Model Output

The travel demand model is used to simulate the conditions before and after a project is completed. Several outputs are produced for each scenario and are compared in order to understand how the completed project will impact traffic in the study region. These are important inputs into the model, and generally include the following, which in most cases can be provided for the study area in aggregate or at the sub-geography level.

g. **Vehicle Hours Traveled –** The total hours of travel time (usually daily average hours) for the users of the transportation system. Changes in vehicle hours traveled have an economic impact that are quantified using wage rates.

h. **Vehicle Miles Traveled –** the total distance traveled (usually in daily average miles) for the network users. Vehicle operating costs, safety costs, and emissions are all dependent on vehicle miles traveled.

i. **Delay –** Vehicle delay (usually in daily average hours) is the difference in vehicle hours traveled between expected traffic conditions and free-flow conditions. Delay is particularly important in assessing the impact of improvements to rail crossings.

j. **Trips –** Vehicle trips (usually measure in a daily average count) are used to understand total traffic volumes, and the distribution of these volumes across geography as well as time.

k. **Occupancy –** Vehicle occupancy (an average count of people per vehicle) is used in order to accurately assess the impact of changes in vehicle hours traveled, as each occupant is impacted by these changes.

l. **Origin and Destination –** Vehicle trips, hours traveled, miles traveled can be assigned to specific origin-destination pairs in most travel demand models. This is of particular importance in determining which freight trips are internal to the study area, exporting goods from the study area, importing goods into the study area, or passing through.

m. **Trip Purpose –** Most travel demand models break up vehicle trips, hours traveled, and miles traveled by purpose (such as leisure, commute, business, and trucking). This division enables the model to apportion costs and benefits to the correct economic sector (such as households, businesses, or the freight industry specifically).

- External Data

Most of the data required for the translation of costs and benefits from changes in travel efficiencies and pavement conditions are available from public sources such as federal and state agencies. These data are readily available and are updated with regular frequency (in most cases, at least on an annual basis).

n. **Wage Rates –** Wage rates are used to set a financial value for changes in the time spent by users of the transportation system.

o. **Fuel Costs –** Fuel costs are needed to quantify the change in costs of user vehicle operation, before and after the project is completed.

p. **Non-Fuel Vehicle Operating Costs –** The expenses of vehicle operation, other than fuel, must be known in order to give a value to the change in costs born by system users resulting from changes in aggregate mileage and/or delay.

q. **Crash Rates –** Some projects result in changes in in aggregate mileage travelled. This is accompanied by a proportionate change in traffic accidents. Crash rates are means by which this change is calculated. Some projects (pavement improvement projects for example) may result in a change in the rate of traffic accidents.

r. **Crash Values –** The crash rates above can be used to calculate and expected change in the count of traffic accidents. In order to translate these accidents to a dollar amount, prescribed values (usually provided by federal agencies) are used.

s. **Emissions Rates –** A transportation project may impact pollution levels through changes in user miles traveled, average speeds, or delay. These factors determine the change in fuel burned. This increase or decrease in the amount of fuel burned translates to a change in the emission of pollutants, which is calculated by using emissions rates.

t. **Emissions Values –** Emissions values are used to assign a dollar value to the change in emissions caused by the project.

u. **Shipping Costs –** One of the important benefits of diversion of freight from truck to rail is the price differential between the two modes. In order to estimate these benefits, current shipping costs for both truck and rail must be used.

v. **Value of Freight –** In order to understand impacts to logistics costs, inventory costs must be considered. In order to estimate how these costs will fluctuate, the value of the freight moving though the study area must be input into the model.

w. **Volume of Freight –** The freight systems are interconnected. While some commodities are more suited to one mode over another, many may be transported in several ways, depending on the relative benefits of one mode over another. Information about the volume of each commodity, by mode and origin-destination pair, is necessary to estimate the systemic effect of freight rail improvements.

x. **Weight per Truckload –** Once the volume of diversion from truck to rail (or vice versa) is estimated by the model, the volume must be converted into a number of truckloads, so that the travel demand model can accurately reflect the resulting change in congestion.

y. **Buffer Indices –** Freight carriers must allow for uncertainty in turn times by allocating extra time per turn, in case of unexpected delays. These buffer times increase as the uncertainty increases, which increases turn times. Buffer indices are measures of buffer time, as a percentage of travel time.

z. **Maintenance and Operations Costs –** If the user does not know the future costs of maintaining and operating the project improvements, estimated values calculated from historical expenditures can be used.

aa. **Pavement Conditions –** Changes in pavement conditions can lead to changes in travel-times, vehicle operating costs, crash rates, and congestion. To estimate the impact of pavement improvement projects, accurate measures of the current pavement conditions are needed.

bb. **Length of Road Segments –** Pavement conditions do not apply to the road network evenly. Each road segment has its own condition. To calculate the impact of pavement conditions accurately, the length of each road segment must be known.

cc. **Consumer Price Index –** Not all values of the inputs will be given in dollar values from the same year. In order to account for inflation over time the Consumer Price Index (CPI) is employed.

5.1.3 Summary of Data Requirements

Not all of the data inputs are needed for every project and not all data needed are available. Some only apply to specific types of projects (for example, current and future pavement states are only required for the State of Good Repair Module). Some information is not required but may be useful. For example, maintenance and operations costs contribute to the accuracy of the analysis, but it can be carried out with or without their inclusion. The following table (Table 5.1) lists the inputs for the model, their potential data sources, and whether or not they are required for a specific module.

Table 5.1 Data Requirements

Description	Roadway	Operational and Safety	Freight Rail	Sources
Construction Costs	Yes	Yes	Yes	User
Maintenance and Operations	No	No	No	User, State Financial Records
Construction Schedule	Yes	Yes	Yes	User
List of Improvements	Yes	Yes	Yes	User
Future Pavement Condition	No	No	No	User
Study Timeline	Yes	Yes	Yes	User
Discount Rates	Yes	Yes	Yes	User
Rail-Truck Diversion Rate	No	No	Yes	CS estimated based on FAF4 and TEF model
Annual Average Traffic Data	No	Yes	Yes	User
Vehicle Hours Traveled	Yes	No	No	Travel Demand Model
Vehicle Miles Traveled	Yes	No	No	Travel Demand Model
Delay	Yes	No	No	Travel Demand Model
Trips	Yes	No	No	Travel Demand Model
Occupancy	Yes	No	No	Travel Demand Model
Origin and Destination	No	No	No	Travel Demand Model
Trip Purpose	Yes	No	No	Travel Demand Model
Wage Rates	Yes	Yes	Yes	Bureau of Labor Statistics
Fuel Costs	Yes	Yes	Yes	US Energy Information Administration (updated annually)

Vehicle Operating Costs	Yes	Yes	Yes	AAA, ATRI (updated annually)
Crash Rates	Yes	Yes	Yes	Highway Statistics (FHWA), State DOT's (update when new data becomes available)
Crash Values	Yes	Yes	Yes	US Department of Transportation (update when new data becomes available- usually with INFRA grant guidance)
Emissions Rates	Yes	Yes	Yes	EPA, Department of Energy, MOVES model
Emissions Values	Yes	Yes	Yes	US Department of Transportation (update when guidance changes)
Shipping Costs	No	No	Yes	Bureau of Transportation Studies, TIGER Methodology
Value of Freight	No	No	Yes	FAF4 – Update with FHWA FAF updates
Volume of Freight	No	No	Yes	FAF4 – Update with FHWA FAF updates
Weight per Truckload	No	No	Yes	FAF4 – Update with FHWA FAF updates
Consumer Price Index (CPI)	Yes	Yes	Yes	Bureau of Labor Statistics (update annualy0

5.2 Economic Impact Models

After having considered transportation efficiency benefits of roadway capacity, operational, state-of-good-repair, or freight rail improvements with a Cost-Benefit Analysis, the next step is using the direct user benefits as inputs to estimate the economic impact analysis at the local, regional, or state level. Economic impact is usually calculated using a model such as REMI, Implan, Transight, or TREDIS. These models measure the impact of a transportation project by industry on output, value added, taxes, employment, and personal income from changes in spending patterns or improved market access. These models consider business productivity and economic development impacts that are not represented in transportation system efficiency tools.

The inputs required by the economic impact model are summarized into a file that feeds into the software. These inputs include the project costs, reduced travel time and vehicle operating costs, change in shipping costs, alleviation of traffic congestion, and improved transportation system reliability. Other benefits such as reduction in emissions have no multiplier effect in the regional economy.

The model uses input-output tables (or economic multipliers) to estimate the direct, indirect, and induced effects on the economy and on employment, including short-term (construction) and long-term (operations) jobs created or maintained, in the case of state-of-good-repair projects:

- Direct Impacts: Are assessed only in the industries immediately affected by the investment. For example, operation and maintenance jobs in roadways and railways;

- Indirect Impact: It reflects the impact on industries that supply intermediate goods, that is, the demand created for suppliers and contractors in terms of income and employment.

- Induced Impacts: They consider increased household income and their spending behavior. For example, as more jobs are added to the economy or more disposable income is made available, individuals will consume more and generate additional economic activity for industries in general.