

# Multimodal Grain Benefits Model User's Guide

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The purpose of the Multimodal Grain Benefits Model (MGB) is to provide a high-level estimate of the benefits to the grain sector associated with a truck or multimodal transportation project. The truck only model is designed as a method to estimate the impacts to the grain sector associated with a transportation project, such as widening an existing road, therefore reducing congestion. The truck only model uses a benefit cost analysis approach to calculate the vehicle operating cost savings, business and personal time and reliability cost savings, safety benefits, logistics/ freight cost savings, environmental benefits, and economic impacts in the form of business output and the positive effect of wage income. Benefits accruing solely to the grain sector are also calculated as well as a project prioritization factor.

The multimodal model uses a similar benefit cost analysis to calculate vehicle operating cost and freight time cost savings from a reduction in wait times, associated with a project. The multimodal model is designed to be used to estimate the impacts of a project that reduces vehicle wait times for truck, rail, and/or barge at a freight facility. It could also be used to estimate the impacts of a river lock project that would reduce barge delays. This model requires the user to estimate costs, traffic, and reductions in freight delay. Both analyses also calculate the total benefits that are accrued solely by the grain sector, as well as a project prioritization factor.

Figure 1. Truck Model Input

**INPUTS**

Truck Model | Multi Model

**Project Parameters**

State	Iowa	▼
Area Type	Rural	▼
Construction Cost (M\$)		\$77.59
Construction Start Year	2019	▼
Operation Start Year	2025	▼
Constant Dollar Year	2018	▼

**Scenario-Baseline**

Truck Percent		28.6
AADT		15,397
Average Speed (Base)		64.8

**Scenario-Project**

Average Speed (Project)		65.8
Project Length (Miles)		10

**Commodity Mix** +

Calculate Results

User inputs for the truck only model include the following:

- State: The US state in which the project is undertaken, changes the default commodity mix
- Project Area Type: Can be Urban, Suburban, or Rural, depending on the project
- Cost: The total cost of the project in 2019, in millions of dollars

- Construction Start Year: The year in which construction begins
- Operation Start Year: The year in which the project begins operation
- Truck Percent: The percent of vehicles on the project roadway that are commercial freight trucks
- Average Annual Daily Travel (AADT): The average number of vehicle trips on the project roadway each day
- Average Speed Base: The average speed of vehicles on the existing roadway in miles per hour (mph)
- Average Speed Project: The estimated average speed of vehicles on the proposed project roadway
- Project Length: The total distance of the project in miles
- Commodity Mix: If users have specific information on the type of freight moving through the project area, they can override the default here. Percentages are based on the percent of total tonnage per commodity.

Figure 2. Multimodal Model Input

## INPUTS

Truck Model
Multi Model

<b>Project Parameters</b>	
State	Iowa
Area Type	Rural
Construction Cost (M\$)	\$100
Construction Start Year	2020
Operation Start Year	2025
Constant Dollar Year	2018
<b>Truck</b>	
Annual Truck Traffic	60,000
Wait Time Reduction (Hours)	2
<b>Rail</b>	
Annual Rail Traffic	50
Wait Time Reduction (Hours)	2
<b>Barge</b>	
Annual Barge Traffic	750
Wait Time Reduction (Hours)	2
Commodity Mix-Truck	+
Commodity Mix-Barge	+
Commodity Mix-Rail	+
Calculate Results	

User inputs for the multimodal model include the following:

- State: The US state in which the project is undertaken, changes the default commodity mix
- Project Area Type: Can be Urban, Suburban, or Rural, depending on the project
- Cost: The total cost of the project in 2019, in millions of dollars

- Construction Start Year: The year in which construction begins
- Operation Start Year: The year in which the project begins operation
- Annual Truck Traffic: The number of trucks expected to be affected by the project each year
- Annual Rail Traffic: The number of trains expected to be affected by the project each year
- Annual Barge Traffic: The number of barges expected to be affected by the project each year
- Wait Time Reduction: The numbers of hours of delay expected to be reduced by the project, for each mode of transportation
- Commodity Mix: If users have specific information on the type of freight moving through the project area, they can override the default here. Percentages are based on the percent of total tonnage per commodity.

Appendix A shows the default values used in the analysis. The commodity mixes by state for truck, rail, and barge were gathered from the Freight Analysis Framework Data Tabulation Tool, produced by the Federal Highway Administration in conjunction with the Bureau of Transportation Statistics<sup>1</sup>. The output of the models is discussed in further detail in the following sections.

*Figure 3. Truck Model Output*

OUTPUTS	
Benefits and Costs	Present Value (2018)
Vehicle Operating Cost Savings	\$6.83M
Business Time and Reliability Cost Savings	\$5.34M
Personal Time and Reliability Cost Savings	\$2.71M
Safety Benefits	\$4.66M
Freight Time Cost Savings	\$21.84M
Environmental Benefits	\$0.06M
Business Output	\$117.19M
Positive Economic Effect of Wage Income	\$52.40M
Total Benefits	\$211.04M
Capital Costs	\$70.05M
Total Costs	\$70.05M
Benefit / Cost Ratio	3.01 : 1
Total Agriculture Benefits	\$2.87M
Project Prioritization Factor	4.10

<sup>1</sup> <https://faf.ornl.gov/fafweb/Extraction0.aspx>

Figure 4. Multimodal Model Output

OUTPUTS	
Benefits and Costs	Present Value (2018)
Vehicle Operating Cost Savings	\$133.49M
Truck Freight Time Cost Savings	\$28.45M
Rail Freight Time Cost Savings	\$9.19M
Barge Freight Time Cost Savings	\$23.59M
Business Output	\$148.76M
Positive Economic Effect of Wage Income	\$66.52M
<b>Total Benefits</b>	<b>\$410.00M</b>
Capital Costs	\$88.93M
<b>Total Costs</b>	<b>\$88.93M</b>
Benefit / Cost Ratio	4.61 : 1
Total Agriculture Benefits	\$49.12M
Project Prioritization Factor	55.24

## Methodology

### Multimodal Grain Benefits Model

The first step of the MGB model is the cost calculation. Both the truck only and multimodal models calculate cost in the same manner. The construction costs are distributed evenly over the construction period and discounted. All costs and benefits assume a 3 percent discount rate. The model then generates travel impact costs for the baseline (no-build) scenario and the project (build) scenario. The difference in costs between the baseline and project scenario is the cost savings or benefit of the project.

For the truck only model, these costs are then calculated separately for passenger and truck travel. In order to calculate these costs, first the number of trips, vehicle miles traveled (VMT), vehicle hours traveled (VHT), were calculated.

- Trips
  - Annual Trips = Average Annual Daily Traffic (AADT) \* 365
  - Truck Trips = Annual Trips \* Percent of Truck Traffic
  - Passenger Trips = Annual Trips – Truck Trips
- VMT = Trips \* Project Length
- VHT = VMT / Average Speed<sup>2</sup>

The multimodal model uses a similar method. Annual traffic is simply multiplied by the wait time reduction, to yield the total delay hours reduced.

<sup>2</sup> If the change in average speed is less than 1 mph between the baseline and project scenarios, the baseline speed is rounded down to the nearest mph and the project speed is the baseline speed plus 1 mph.

- $\text{Total Delay Hours Reduced} = \text{Annual Traffic} * \text{Wait Time Reduction}$

### Vehicle Operating Cost Savings

The truck only model calculates both truck and passenger vehicle operating cost which is the cost per hour of operating a passenger vehicle or truck. This factor includes maintenance, tires, mileage-based depreciation, and insurance. Fuel costs are also calculated and added. An increase in speed in the project scenario will result in less vehicles hours of travel, leading to less operating costs, consequently creating a benefit.

- Vehicle Operating Costs
  - $\text{Base Operating Cost (Truck and Passenger)} = (\text{VHT} * \text{Vehicle Operating Cost per Hour})$
  - $\text{Fuel Operating Cost (Truck and Passenger)} = (\text{VHT} * \text{Gallons per Hour}) * \text{Fuel Cost per Gallon}$

The multimodal model calculates these same costs for truck, rail, and barge. In the multimodal model it is assumed that the vehicle is idle while delayed. Therefore, operating costs are calculated differently, as there is a lower cost associated with an idle vehicle. This results in rail operating costs being zero. It is unlikely that rail freight delayed at a freight facility would require crews or locomotives to sit idle, therefore this cost is not calculated. The truck operating cost includes truck capital costs, maintenance costs, insurance costs, license costs, driver compensation, and an idle fuel cost. The barge operating cost assumes that no towboat fuel is used while the barges sit idle, therefore it includes no fuel cost, but rather an hourly towboat crew cost, towboat maintenance cost, towboat crew cost, and barge capital costs. Barge capital costs are different for dry and tanker barges. The model assumes the percentage of tanker barges based on the state commodity data. These hourly costs are then multiplied by the total delay hours to yield the total vehicle operating cost.

- Vehicle Operating Costs
  - $\text{Hourly Truck Operating Cost} = \text{Hourly Truck Capital Costs} + \text{Hourly Maintenance Cost} + \text{Hourly Insurance Cost} + \text{Hourly License Cost} + \text{Hourly Crew Compensation} + \text{Hourly Idle Fuel Cost}$
  - $\text{Total Truck Operating Cost} = \text{Hourly Truck Operating Cost} * \text{Total Delay Hours}$
  - $\text{Hourly Barge Operating Cost} = \text{Hourly Towboat Non-Fuel Costs} + \text{Hourly Barge Capital Cost}$
  - $\text{Total Barge Operating Cost} = \text{Hourly Barge Operating Cost} * \text{Total Delay Hours}$

### Business and Personal Time and Reliability Cost Savings

In the truck only model, value of time is the crew cost for trucks and the personal time costs for passenger vehicles. Time- savings result from multiplying the number of crew or passengers per vehicle by the crew or passenger cost per hour factor for each crew- member/passenger, and then multiplying by the VHT in each scenario. The difference between the two scenario costs is the cost savings.

- Value of Time
  - $\text{Truck Business Time Cost} = (\text{Number of Crew per Vehicle} * \text{Crew Cost per hour per crew member}) * \text{Truck VHT}$
  - $\text{Passenger Business Time Cost} = (\text{Number of Passengers per Vehicle} * \text{Passenger Cost per Hour per Passenger}) * (\text{Passenger VHT} * \text{Percentage of Business Personal Time})$

- Personal Time Cost = (Passengers per Vehicle \* Passenger Cost per Hour per Passenger)  
\* (Passenger VHT \* Percentage of Passenger Personal Time)

The multimodal model does not separately calculate business time cost, but rather includes it as a portion of the total vehicle operating cost. Furthermore, it does not calculate personal time cost, as there should be no personal vehicles involved in the types of projects the multimodal model is designed for.

### Environmental and Safety Benefits

The truck only modal next calculates environmental and safety costs. Environmental costs are the truck and passenger vehicle emissions cost. Reduced congestion results in lower idle times for all vehicles, which reduces vehicles emissions per trip. Emission costs are calculated using the per hour rate for Volatile Organic Compounds (VOCs), Nitrogen Oxide (NOx), Sulfur Dioxide (Sox), Particulate Matter (PM), and Carbon Dioxide (CO<sub>2</sub>). Safety costs are the truck and passenger property damage, injury, and fatality costs. The project scenarios assume a decrease in accident rates, based on the type of project, which reduces safety costs.

- Environmental Costs (Truck and Passenger)
  - VHT x Environmental Cost per Hour
- Safety Costs (Truck and Passenger)
  - ((VMT / 100,000,000) \* Fatality Rate per 100m VMT) x \$ per Fatality
  - ((VMT / 100,000,000) \* Injury Rate per 100m VMT) \* \$ per Injury
  - ((VMT / 100,000,000) \* Property Damage Rate per 100m VMT) \* \$ per Property Damage

The multimodal model does not calculate safety or environmental costs. Environmental costs are not included because in the rail and barge scenarios it is assumed there is no fuel being consumed while they wait, therefore there is no environmental cost. In the truck scenario there is an environmental impact, as the trucks are assumed to be idling, however this is negligible as the fuel consumption rate is much lower than in the truck only model, where the vehicle is likely traveling along a highway. Safety costs are not calculated because there is no reason to believe that a reduction in idle time would reduce the frequency of travel accidents.

### Freight Time Costs

Freight time costs represents the costs to industries that produce or consume the freight goods on vehicles moving through the project area. The freight time cost savings consists of commodity time costs, perishability costs, and just in time costs. These factors were calculated in the same manner for the truck only model and the multimodal model, using a methodology developed by Fitzroy, et al. with EDR group.<sup>3</sup>

First, the commodity time cost for each commodity was calculated by multiplying the tons per vehicle by the commodity percent of freight, then by the commodity cost per hour, and then by total buffer time

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<sup>3</sup> Fitzroy, Stephen, et al., New Methods for Assessing the Costs of Delay and Reliability on Major Highway Corridors: A Commodity-Focused/Industry Sector Approach for Addressing Freight Planning in MAP-21. ITED Conference 2014. <https://www.edrgroup.com/pdf/Fitzroy-ITED-2014.pdf>

<sup>4</sup>for the truck model, or by total delay hours for the multimodal model. This calculation repeats for each commodity moving through the POE. The commodity cost per hour for each commodity was calculated through EDR's methodology which assumes an hourly return on capital of 10 percent, divided by 5,400, with 5,400 being the estimated number of productive hours in a year. This was then multiplied by the cost of the good as reported at the POE to give the commodity cost per hour. This represents an hourly opportunity cost of the good not being at its destination.

The perishability cost was also estimated based on the calculated buffer time and using EDR's methodology. Perishability cost is the loss in value from goods spoiling during transport. This applies to goods that need to be fresh at their destination such as fruits and vegetables. A calculation similar to the commodity time cost calculation was used. Buffer time or delay hours were multiplied by the tons per vehicle, then by the commodity percent of freight. This was then multiplied by the perishability cost factor, then by the perishability commodity factor. A perishability cost factor of \$0.001 per hour was used, based on EDR's methodology. Perishability commodity factors were also assigned to goods based on EDR methodology. Just in time cost was calculated in the same way, using a just in time cost factor and a just in time commodity factor in place of the perishability factors. Just in time commodity factors were used based on EDR methodology, with a just in time cost factor of \$0.002.

- Total Freight Time Cost = Commodity Time Cost + Just in Time Cost + Perishability Cost
  - Commodity Time Cost= (Truck Buffer VHT or Total Delay Hours) \* Tons per Vehicle \* Commodity Percent of Freight \* Commodity Cost per Hour
    - Commodity Cost per Hour = Commodity Price \* (0.1/5400)
  - Just in Time Cost = (Truck Buffer VHT or Total Delay Hours) \* Tons per Vehicle \* Commodity Percent of Freight \* Just In Time Cost Factor \* Just in Time Commodity Factor
  - Perishability Cost = (Truck Buffer VHT or Total Delay Hours) \* Tons per Vehicle \* Commodity Percent of Freight \* Perishability Cost Factor \* Perishability Commodity Factor

Transportation cost savings are calculated annually for both the baseline and project scenarios. The project costs are then subtracted from the baseline costs to produce annual project benefits for each cost category. These annual benefits are discounted, then summed to provide total discounted project benefits for each cost category.

### Economic Effects

The economic effects of the project are also calculated for both the truck only model and the multimodal model. These include the business output and wage income. Business output is associated with construction spending on the project and is presented as the sum of worker wages and business income. The positive economic effect of wage income is the impact of increased worker income associated with construction spending on the economy.

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<sup>4</sup> Truck buffer time is the extra time required to ensure 95% of trips are on time. The model uses a congestion factor of 1.05 to represent a national rural average congestion. Total truck vht is multiplied by 1.05 to yield buffer time.



- $\text{Business Output} = \text{Discounted Construction Cost} * \text{Business Output Multiplier}^5$
- $\text{Economic Effect of Wage Income} = \text{Discounted Construction Cost} * \text{Wage Income Multiplier}^6$

### Project Prioritization Factor

In order to calculate the benefits solely accrued by the grain sector, the project and baseline costs were calculated a second time, however only the benefits attributable to grain sector activity were counted as represented by the percentage of freight attributable to grain sector commodities. This percentage was then applied to the total number of freight trips, to determine the number of agricultural sector trips. The cost savings were then calculated a second time using this focused number of trips. This resulted in total benefits that are directly accrued to the agricultural sector.

The total benefits and costs are shown in the final results table for each project. Each benefit is summed to calculate the total discounted benefit. The total discounted benefits are then divided by the total discounted costs to calculate the benefit cost ratio of the project. A benefit cost ratio of greater than 1.0 is positive indicating that the benefits of building the project outweigh the cost. The agricultural sector only benefits are also divided by the cost of the project, the multiplied by 100 to calculate the project prioritization factor. The project prioritization factor is not a cost benefit ratio, as it is not possible to allocate a specific portion of the total project cost to the grain sector. Rather, the project prioritization factor provides an estimate of the relative benefit to the grain sector per dollar spent on the transportation project. A higher project prioritization factor means that the project provides more benefits per dollar to the grain sector relative to a project with a lower project prioritization factor. The project prioritization factor should not be used as a sole factor to select projects, but used as a one point of comparison when comparing potential projects.

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<sup>5</sup>Business Output Multiplier changes based on Urban, Suburban, or Rural classification

<sup>6</sup>Wage Income Multiplier changes based on Urban, Suburban, or Rural classification

## Assumed Values

The default values used for this analysis were obtained from multiple sources and are displayed in Table 1 and 2. All costs have been inflated to 2019 dollars. Additionally, for the truck only model, it was assumed that passenger vehicles are used 42.5% of the time for business and 57.5% of the time for personal use.

**Table 1. MGB Model Truck Only Default Values**

Assumption	Passenger	Truck
Persons per Vehicle (Business)	1.2	1.1
Persons per Vehicle (Personal)	1.6	-
Crew Cost Factor (\$/hr per Crew Member) <sup>7</sup>	-	\$28.75
Passenger Personal Cost Factor (\$/hr per occupant)	\$14.74	-
Passenger Business Cost Factor (\$/hr per occupant)	-	\$27.52
Environmental Cost \$/hr	\$0.03	\$0.62
Vehicle Operating Cost (\$/hr)	\$5.03 <sup>8</sup>	\$37.89 <sup>9</sup>
Fatality Accidents per 100m VMT	1.08 <sup>10</sup>	0.2 <sup>11</sup>
Personal Injury Accidents per 100m VMT	77 <sup>10</sup>	9.7 <sup>11</sup>
Property Damage Accidents per 100m VMT	200 <sup>10</sup>	157 <sup>11</sup>
\$ per Fatalities Accident <sup>7</sup>	\$9,967,928	\$9,967,928
\$ per Personal Injury Accident <sup>7</sup>	\$180,700	\$180,700
\$ per Property Damage Accident <sup>7</sup>	\$4,415	\$4,415

**Table 2. MGB Model Multimodal Default Values**

Assumption	Value
Tons per Truck	24
Tons per Train	21,100
Tons per Barge	1,500
Truck Hourly Operating Cost <sup>7</sup>	\$52.08
Towboat Hourly Operating Cost <sup>12</sup>	\$228.63
Dry Barge Hourly Operating Cost <sup>12</sup>	\$6.55
Tanker Barge Hourly Operating Cost <sup>12</sup>	\$36.24
Barges per Towboat	15
Railcars per Train	110

<sup>7</sup> <https://atri-online.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf>

<sup>8</sup> <https://exchange.aaa.com/wp-content/uploads/2015/04/Your-Driving-Costs-2015.pdf>

<sup>9</sup> <https://atri-online.org/wp-content/uploads/2018/10/ATRI-Operational-Costs-of-Trucking-2018.pdf>

<sup>10</sup> [https://www.bts.gov/archive/publications/national\\_transportation\\_statistics/table\\_02\\_17](https://www.bts.gov/archive/publications/national_transportation_statistics/table_02_17)

<sup>11</sup> [https://www.bts.gov/archive/publications/national\\_transportation\\_statistics/table\\_02\\_23](https://www.bts.gov/archive/publications/national_transportation_statistics/table_02_23)

<sup>12</sup> Taken from USACE Economic Guidance Memorandum 05-06 and inflated using the BLS Inland Waterways Towing Transportation Price Index