Distribution Factor-Line Girder Analysis Tutorial

DF3 – Distribution Factor Analysis (NSG-LRFR) Example

DF3 - Distribution Factor Analysis (NSG - LRFR)

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Review Distribution Factor Analysis

This example describes the distribution factor analysis feature in BrDR to determine the adequacy of a superstructure for a standard gage or non-standard gage vehicle.

Distribution Factor Analysis Method of Solution

The Distribution Factor Analysis feature computes live load distribution factors for a vehicle traveling in a specified path along the length of the superstructure. This feature allows you to analyze a bridge for standard gage or non-standard gage vehicles.

A 3D and Line Girder finite element analysis of the superstructure is performed, moment and shear live load distribution factors are computed for a vehicle traveling along user-specified paths along the length of the superstructure. The computed distribution factors are then used to perform a rating analysis using traditional Line Girder analysis techniques.

In the 3D finite element model, the deck is modeled as shell elements and the girders are modeled as beam elements. The deck is always included in the model regardless of whether the girders are composite with deck. Diaphragms are not included in the 3D finite element model.

BrDR determines which nodes in the 3D FE model should be loaded with the vehicle by using the vehicle path location and vehicle wheel description entered by the user. Unit loads are placed at each of these nodes in the 3D FE model and the resulting moment and shear element forces in the beam elements are stored. Moment and shear influence surfaces are generated from these element forces. The influence surfaces are then loaded with the vehicle traveling along the user-defined vehicle path. The moments and shears in the girders due to the actual distribution of the vehicle through the deck are then computed.

A Line Girder finite element analysis is then performed for each girder. The Line Girder FE model consists of the girder modeled as beam elements. The nodes in the Line Girder FE model are at the same locations as the nodes in the 3D FE model.

Unit loads are placed at each node along the girder in the Line Girder FE model and the moment and shear influence lines are generated for the girder. These influence lines are then loaded with the axle weights of the vehicle traveling along the superstructure and the resulting moments and shears in the girder are then computed.

Moment and shear distribution factors are computed by dividing the 3D model moments and shears by the Line Girder model moments and shears. These distribution factors are the ratio of the 3D actions to the Line Girder actions. The critical moment distribution factor is chosen for each vehicle path by first finding the moment distribution factors that correspond to the maximum Line Girder moment and the minimum Line Girder moment. The critical moment distribution factor is the maximum of these 2 moment distribution factors. The critical shear distribution factor is determined in the same manner. A traditional Line Girder analysis of the girder is then performed using these critical distribution factors.

Non-standard gage vehicle description
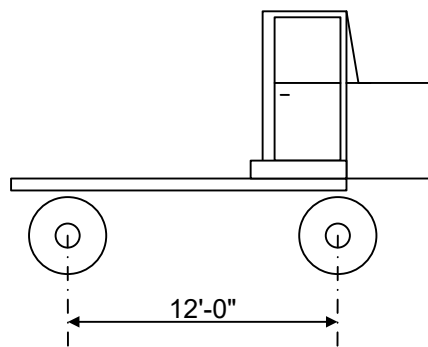
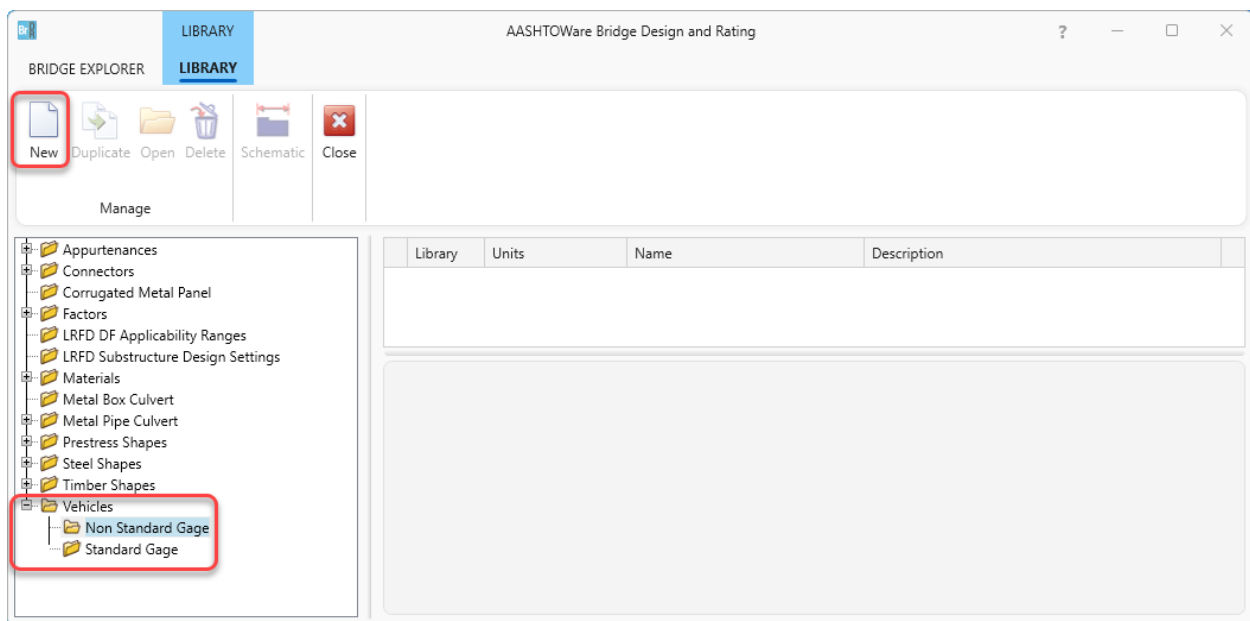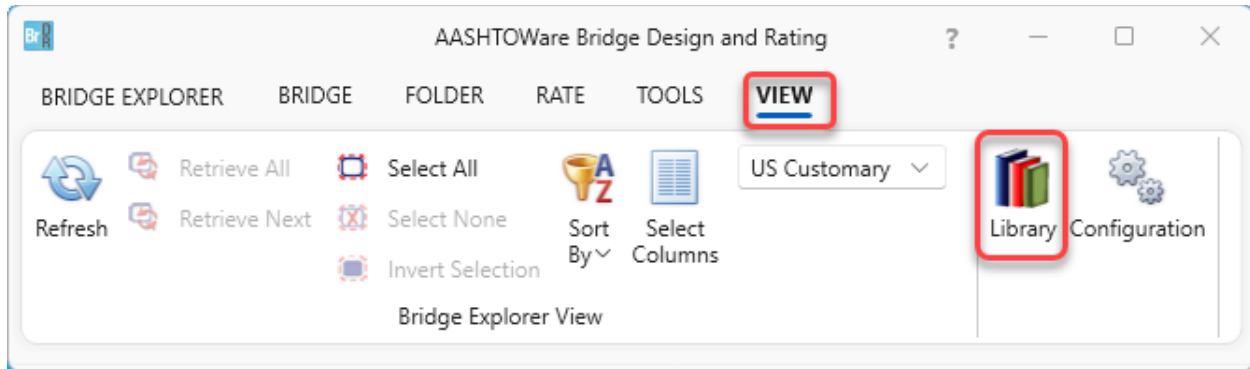| NSG Truck Load Data		
Front Axle	Load/Axle Line	40 kips
	Load/Tire	20 kips
Rear Axle	Load/Axle Line	48 kips
	Load/Tire	12 kips
Total Vehicle Weight		88 kips

Elevation View
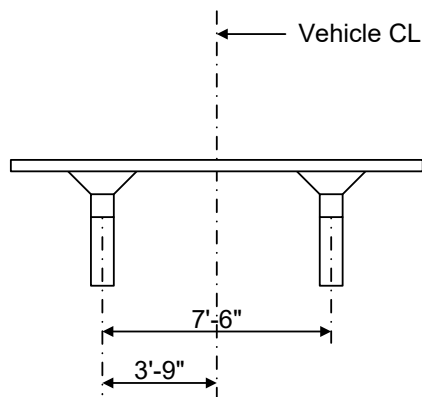
End View of Front Axle
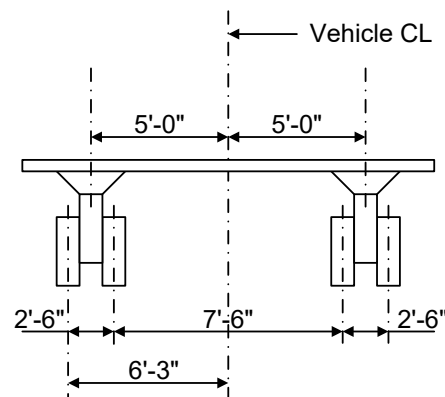
End View of Rear Axle

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The preceding non-standard gage vehicle can be entered in the BrDR vehicle library as follows. Open **the Library Explorer** and select **Non-Standard Gage** in the Library tree. Select **New** from the **Manage** Group to open the **Vehicle: Non-Standard Gage: New Item** window.

The description for the first axle of the vehicle is shown below.

When describing the axles, the **Distance to first wheel** is the distance from the centerline of the vehicle to the first wheel in the axle. This value is a negative value to signify the first wheel is to the left of the vehicle centerline. The following sketch illustrates the terminology used in this window.
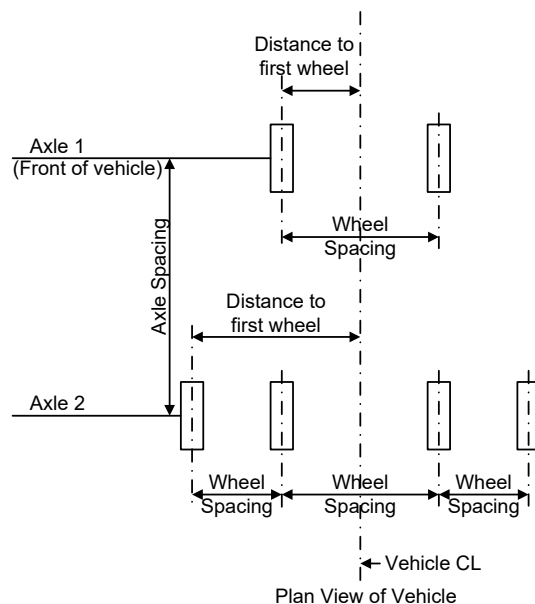
The description of the wheels in the second axle of the vehicle is shown below.

Click **Save** to save this vehicle to the library.

A **schematic** view of the vehicle and each axle is available to verify your data entry by selecting the **NSG Truck** and clicking the **Schematic** button as shown below.

Vehicles: Non-Standard Gage: NSG Truck — □ X

NSG Truck
Vehicle Plan
11/15/2023 3:18:04 PM

Axle 1   Axle 2

Vehicles: Non-Standard Gage: NSG Truck — □ X

NSG Truck
Axle 1
11/15/2023 3:18:04 PM

20.0   20.0

Notes:
* Wheel loads are in kip

Vehicle paths

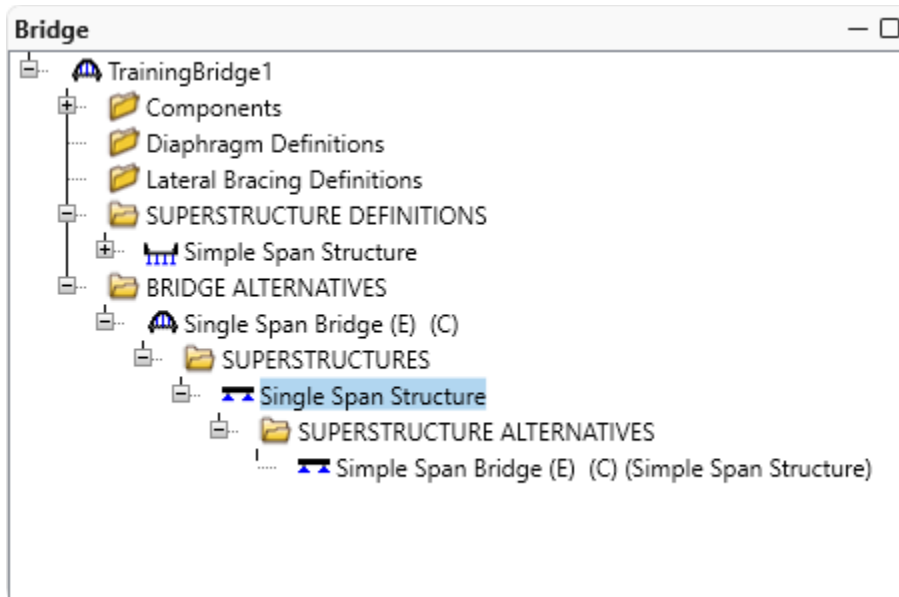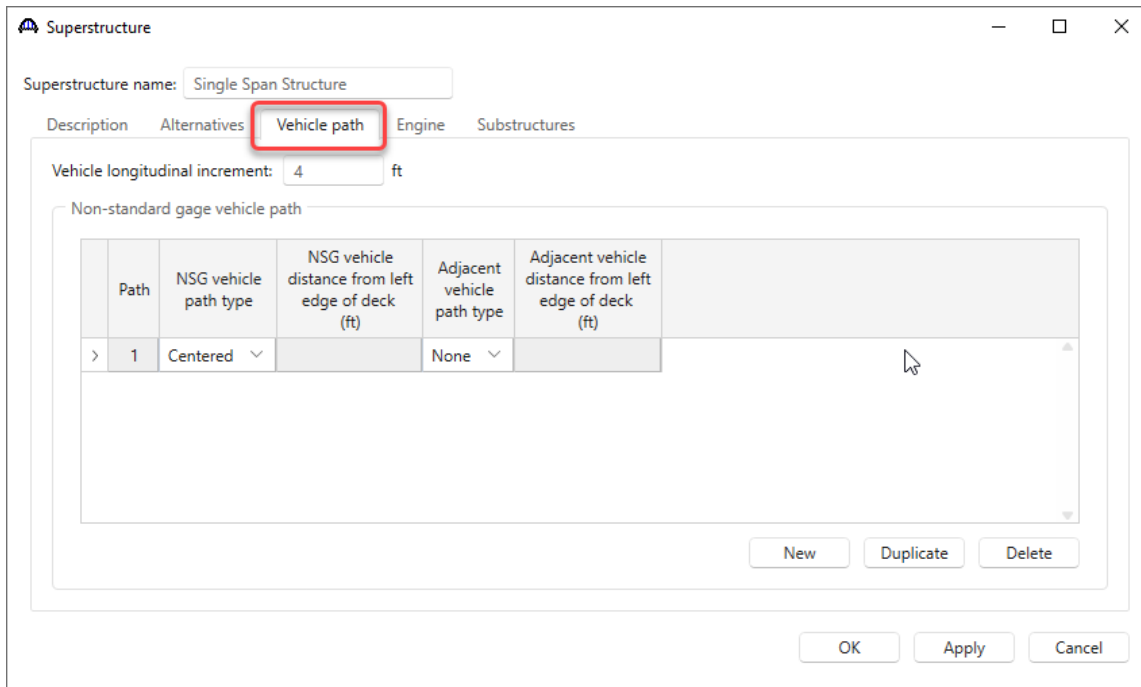The distribution factor analysis is performed at the **SUPERSTRUCTURES** level. When performing a distribution factor analysis on a superstructure the analysis will be performed on the superstructure definition that is assigned to the existing **SUPERSTRUCTURE ALTERNATIVE**. This is necessary since in BrDR a bridge may consist of many superstructure definitions assigned to different locations along the length of the bridge.

In this tutorial, **BID1 (TrainingBridge1)** in the **BrDR sample database** will be analyzed. Open the **Bridge Workspace** for **BID1**. The partially expanded **Bridge Workspace** for **BID1** is shown below. The distribution factor analysis for **Single Span Structure** will perform a 3D and Line Girder analyses of the **Simple Span Structure** which is assigned to the existing superstructure alternative.


Double click on the **Single Span Structure** superstructure window and select the **Vehicle Path** tab.

This tab controls the placement of the vehicle that will be used in the distribution factor analysis. The **Vehicle longitudinal increment** is the longitudinal length increment to use when moving the vehicle along the length of the superstructure. Note that this value can greatly affect the time required for the analysis.

The vehicle path specifies the transverse location of the non-standard gage vehicle and an adjacent vehicle to use in the analysis. The following illustrates where the vehicles would be placed if the **NSG vehicle path** is specified as **Left** and the **Adjacent vehicle path** is specified as **Right**.
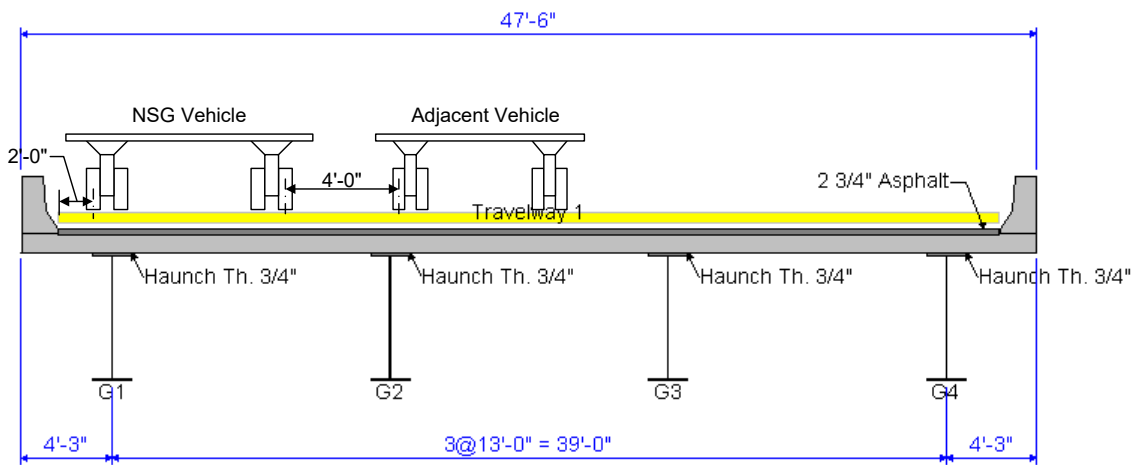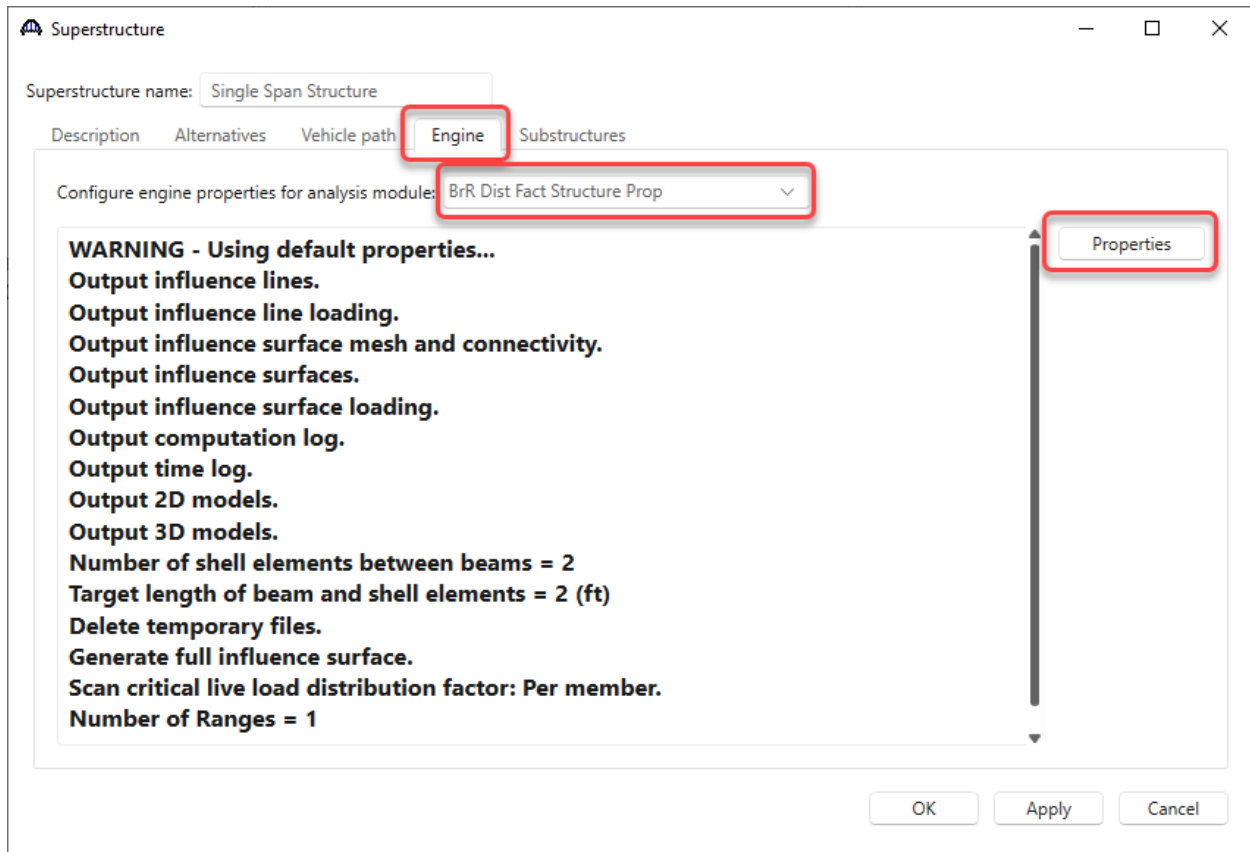

This example uses the **NSG vehicle path** specified as **Centered** and the **Adjacent vehicle path** as **None**. This path is shown below.
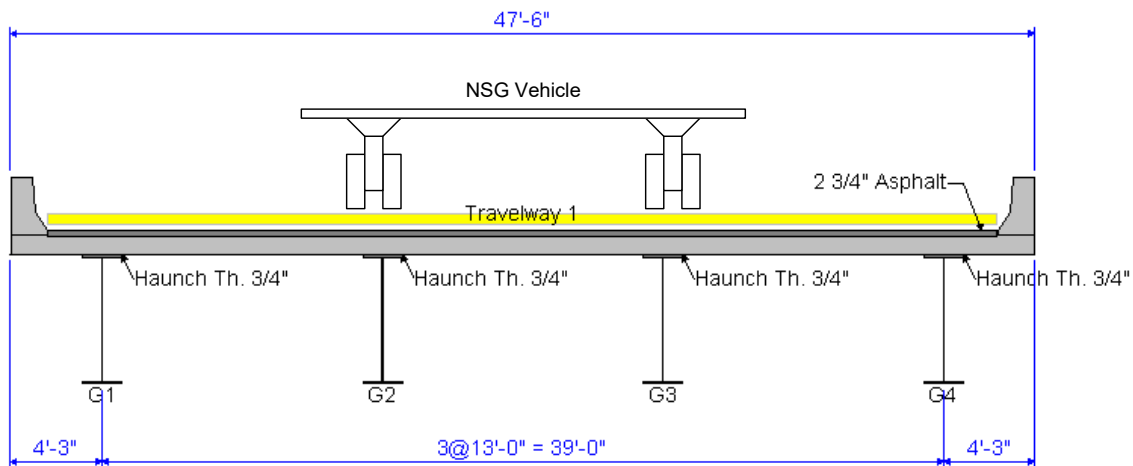
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BrDR Distribution Factor Engine Properties

Select the **Engine** tab in the Single Span Structure superstructure window. The Engine tab allows to specify properties for the analysis engine. Select **BrR Dist Fact Structure Prop** as the analysis module and then click **Properties** button.

The **Properties** button will bring up the below window

This window allows to specify the level of output needed from the analysis and allows to control how the FE models are created and loaded. The **Number of shell elements between beams** and **Target length of beam and shell elements** selections control the size of the elements in the model and greatly influence the time required for the analysis.

Select **Generate path influence surface** under **Influence Surface Control**. The **Scan critical live load distribution factor** selection allows to specify the method for determining the critical distribution factors. The **Per member** option specifies one critical moment and one critical shear distribution factors to be used for the whole member. The **One range per span** option specifies each span in the member has its own critical moment and shear distribution factors. The **Multiple ranges per span** option specifies each range in a span has its own critical moment and shear distribution factors. The length of the range is the span length divided by the entered **Number of Ranges**.

Click **OK** to close the **BrR Dist Fact Superstructure Properties** window and then click **OK** again to close the **Superstructure** window.

Perform Distribution Factor Analysis (NSG – LRFR)

The distribution factor analysis can be initiated by selecting the **Single Span Structure** superstructure in the **Bridge Workspace** tree and clicking the **Analysis Settings** button in the **Analysis** Group of the **DESIGN/RATE** ribbon.
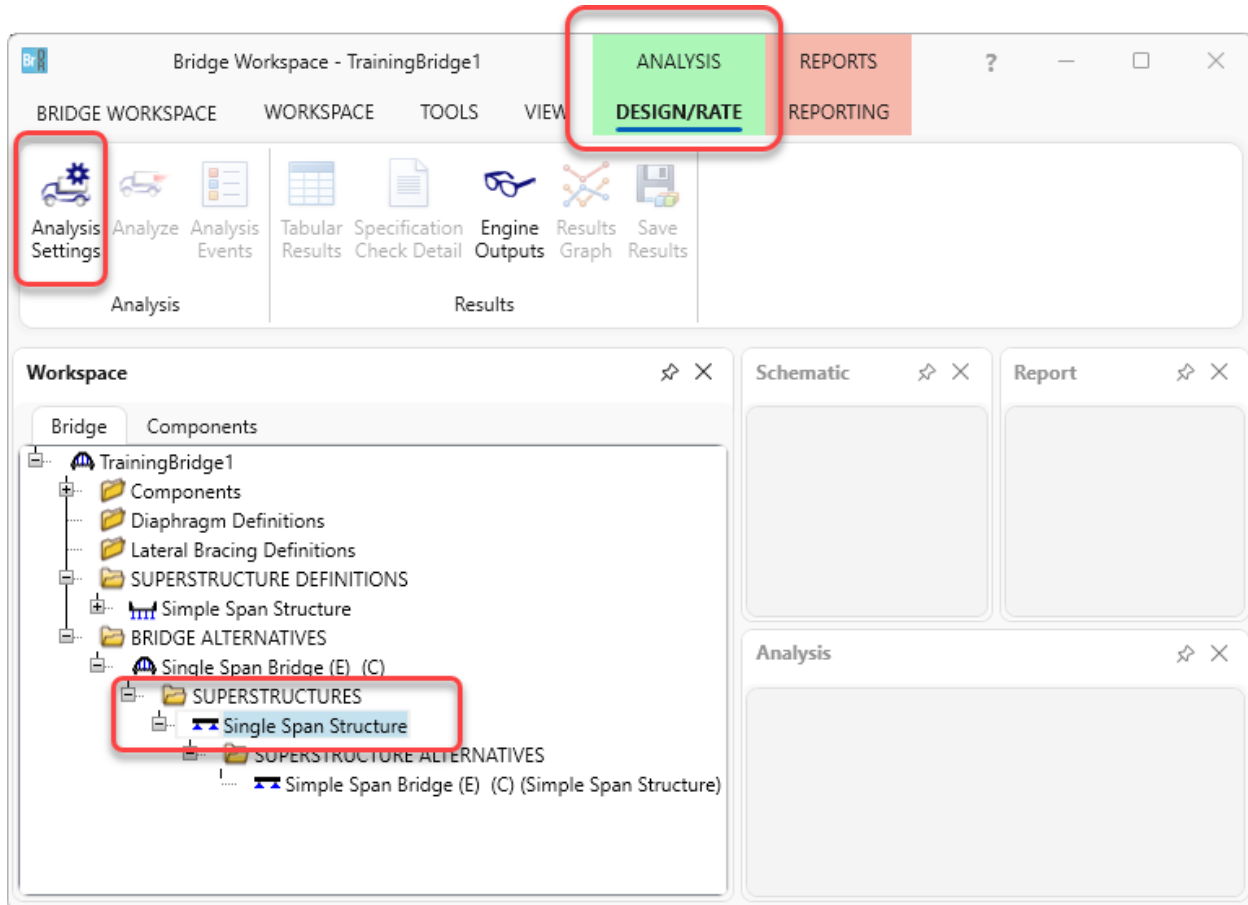
Select **Dist Factor-Line Girder** as the Analysis Type and **LFR** as the Rating Method. This will cause the distribution factor analysis to be performed and LFR analysis will be performed during the traditional Line Girder analysis. Then select the **NSG Truck** as the permit vehicle to use. Note that a standard gage vehicle can also be used in the analysis. A vehicle can be added in the Adjacent lane vehicle as well. However, in this example, no vehicle will be added for the adjacent lane.

Click **OK** to save the settings and close the window.

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Click the **Analyze** button in the Analysis Group to initiate the Distribution Factor-Line Girder analysis.
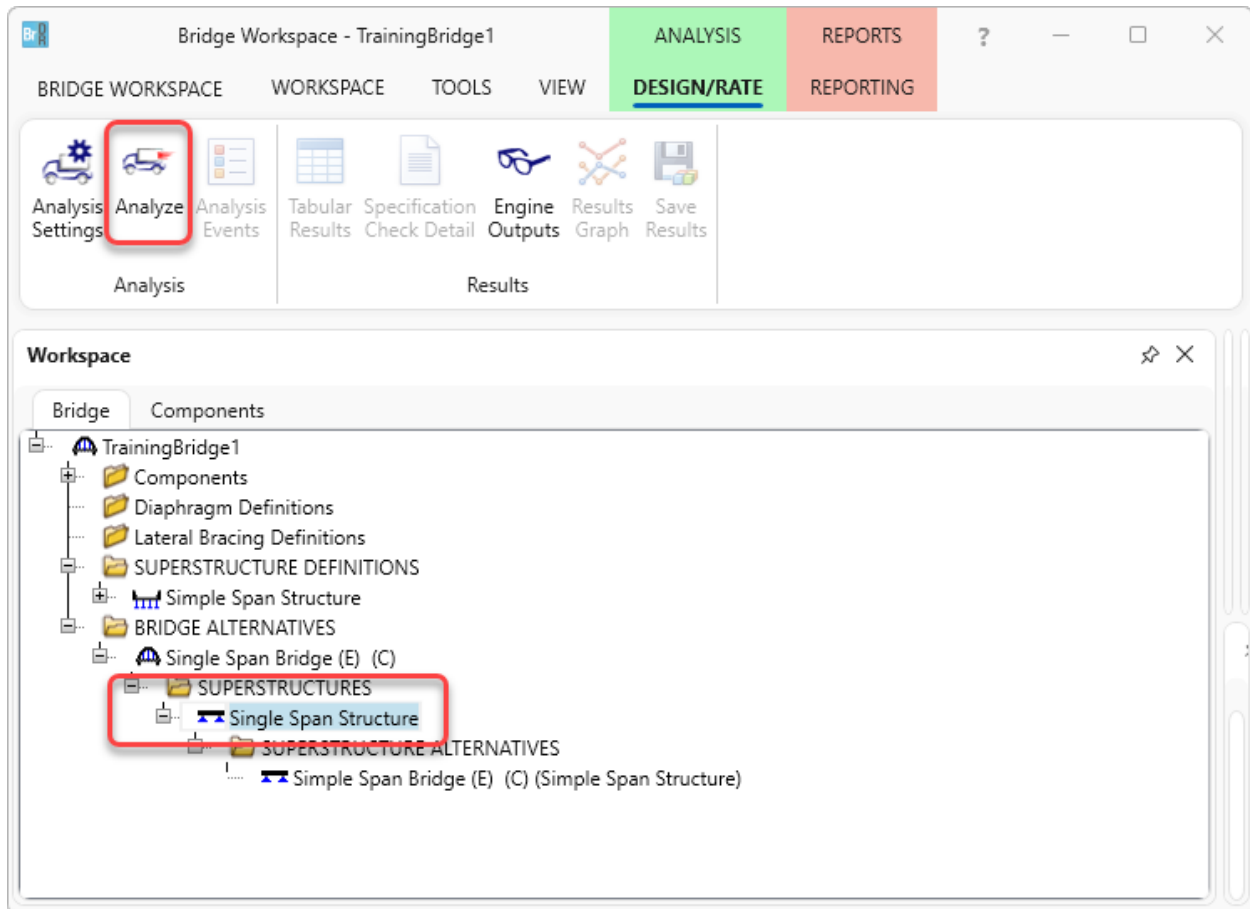
The **Analysis Progress** window will show the progress of the 3D and Line Girder finite element analyses. The AASHTO program is then run for the traditional girder line analysis using the distribution factors computed by the distribution factor analysis.

The output of the distribution factor analysis can be found by selecting **Engine Outputs** from the **Results** group of the **DESIGN/RATE** ribbon when the superstructure is selected in the **Bridge Workspace** tree.
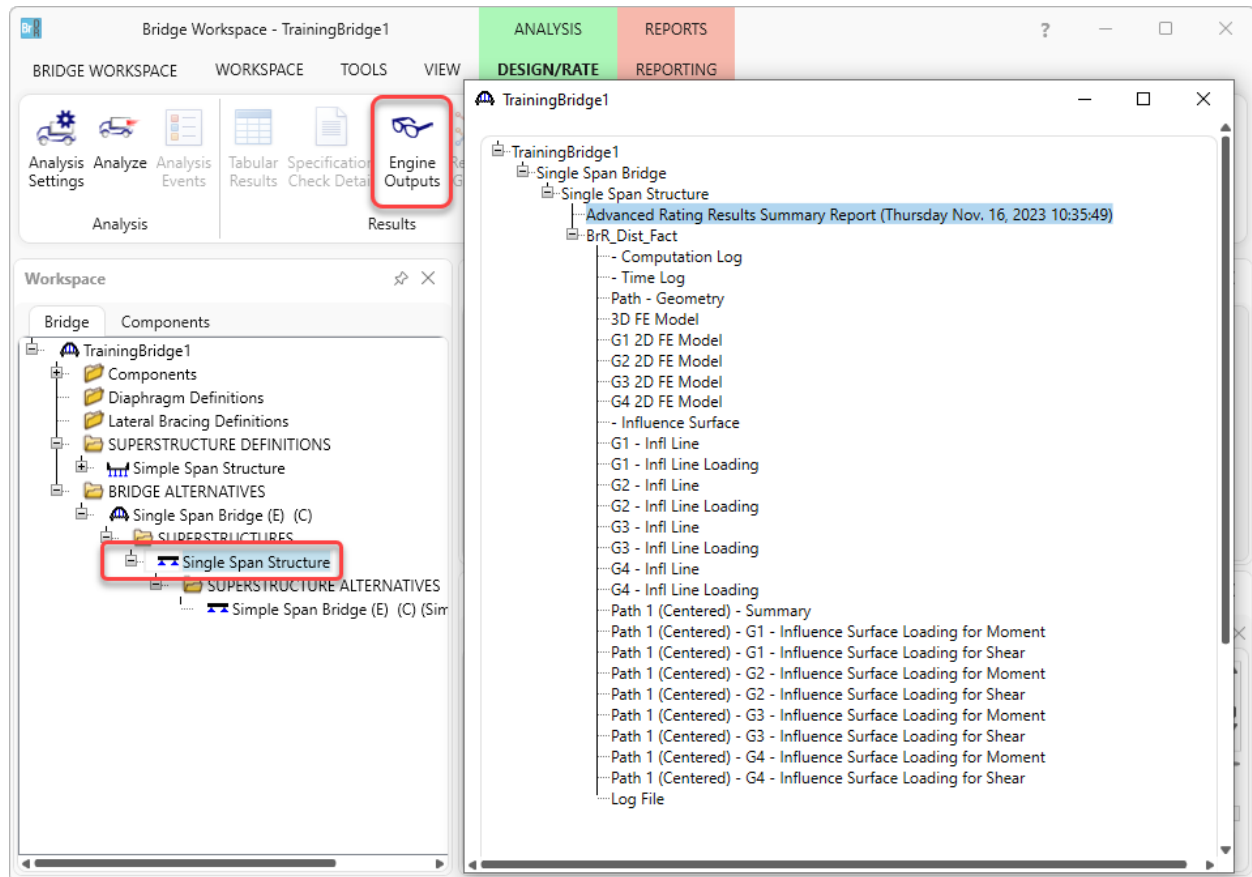
The output of the distribution factor analysis includes the 3D and the Line Girder finite element models, the influence surface and influence lines and their loading.

Double-click the **Advanced Rating Results Summary Report** for a summarized report of the rating. The critical distribution factors used for each girder are also listed in the report.

Bridge Name: Training Bridge 1(LRFD)
Bridge ID: 1
Super Structure: Single Span Structure

Analysis Date: Thursday, November 16, 2023 10:35:35

Permit Vehicle: NSG Truck
Adjacent Permit Vehicle:

Loading Path: NSG (Centered) - ADJ (None)

Member	Permit Capacity (Ton)	Permit Location / Element Name (ft)	Permit Rating Factor	Permit Limit State	Success / Failure
G1	246.32	80.500 (1 - 50.00%)	5.598	STRENGTH-II Steel Flexure Stress	Success
G2	95.23	80.500 (1 - 50.00%)	2.164	STRENGTH-II Steel Flexure Stress	Success
G3	95.40	80.500 (1 - 50.00%)	2.168	STRENGTH-II Steel Flexure Stress	Success
G4	246.08	80.500 (1 - 50.00%)	5.593	STRENGTH-II Steel Flexure Stress	Success

Member	Start Range (ft)	End Range (ft)	Moment Dist. Factor (Lanes)	Shear Dist. Factor (Lanes)
G1	0.000	161.000	0.171	0.132
G2	0.000	161.000	0.324	0.512
G3	0.000	161.000	0.323	0.508
G4	0.000	161.000	0.171	0.133

The results of the **AASHTO LFR** Engine Line Girder analysis of each girder can be viewed by selecting the **member alternative** in the **Bridge Workspace** tree (as shown below) and clicking the **Engine Outputs** button in the **Results** Group.