

AASHTOWare BrDR 7.5.0

Distribution Factor-Line Girder Analysis Tutorial

DF1 – Distribution Factor Analysis (NSG - LFR) Example

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Topics covered:

- Review Distribution Factor Analysis
 - Distribution Factor Analysis Method of Solution
 - Non-standard gage vehicle description
 - Vehicle paths
- BrDR Distribution Factor Engine Properties
- Perform Distribution Factor Analysis (NSG – LFR)

Review Distribution Factor Analysis

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

A 3D and a Line Girder finite element analysis of the superstructure is performed and 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 girder-line analysis techniques.

In the 3D finite element model, the deck is modeled as shell elements and the beams are modeled as frame elements. The deck is always included in the model regardless of whether the beams 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 beams due to the actual distribution of the vehicle through the deck are then computed.

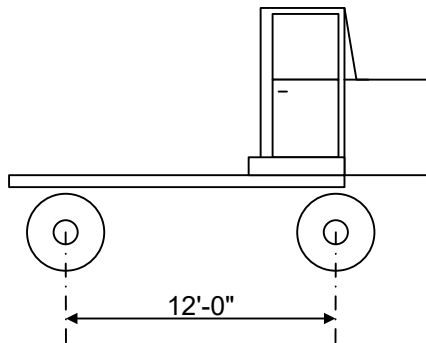
A Line Girder finite element analysis is then performed for each beam. The Line Girder FE model consists of the beam modeled as frame elements. The nodes in the Line Girder FE model are at the same locations as the nodes in the 3D FE model.

Unit loads are placed at each node along the beam in the Line Girder FE model and the moment and shear influence lines are generated for the beam. 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 beam are then computed.

DF1 - Distribution Factor Analysis (NSG - LFR) Example

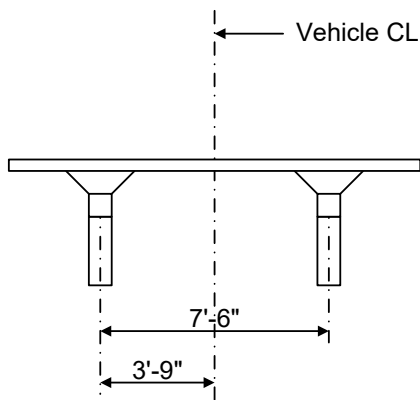
Moment and shear distribution factors are computed by dividing the 3D model moments and shears by the Line Girder model moments and shears. The critical distribution factor is chosen for each vehicle path by first finding the distribution factors that correspond to the maximum 3D moment, the minimum 3D moment, the maximum 3D shear and the minimum 3D shear. The critical distribution factor is the maximum of these 4 distribution factors. A traditional girder line analysis of the beam is then performed using this distribution factor.

Non-standard gage vehicle description

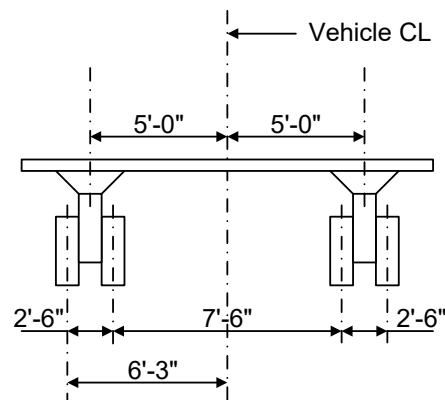


Elevation View

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



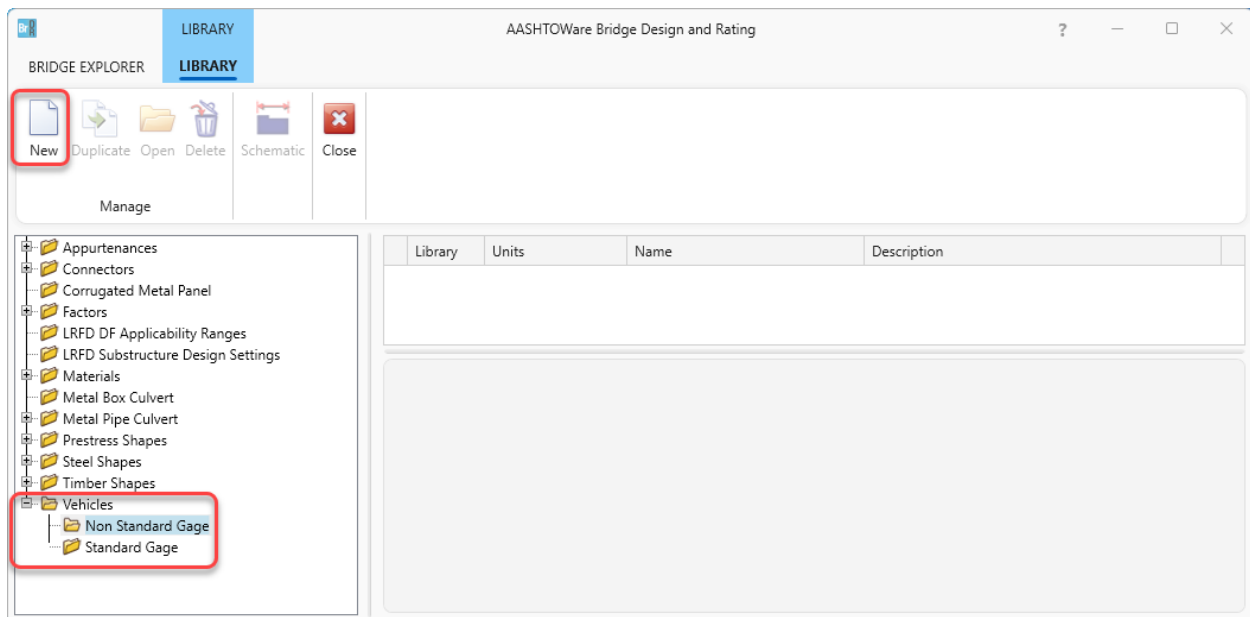
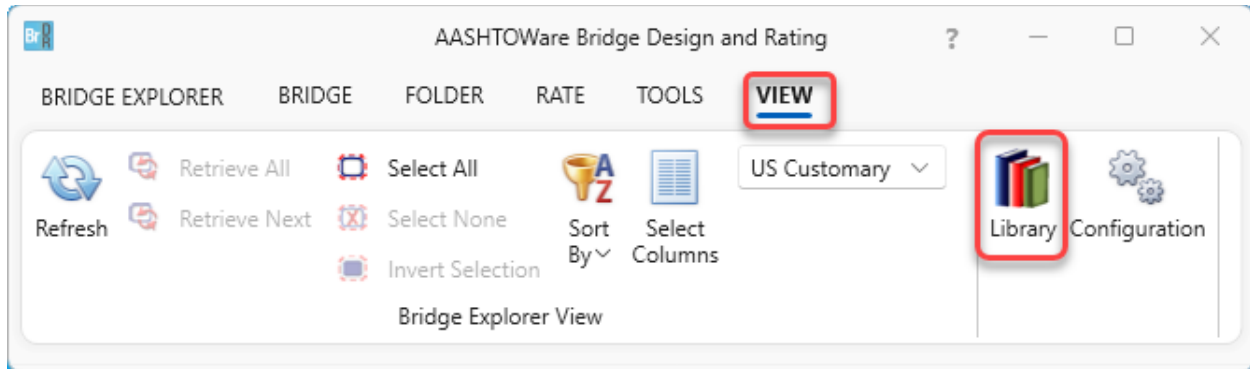
End View of Front Axle



End View of Rear Axle

DF1 - Distribution Factor Analysis (NSG - LFR) Example

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.



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

Vehicle: Non-Standard Gage: New Item

Name:

Description:

Store units as: ☒ US ☐ SI

Library: ☐ Standard ☒ Agency defined ☐ User defined

Description

Axes

	Axle	Distance to first wheel (ft)	Axle spacing (ft)	Total axle load (kip)
	1	-3.75		40
>	2	-6.25	12	0

Totals: 12.00 40.00

New Duplicate Delete

Wheels

Axle: 1

	Wheel	Wheel spacing (ft)	Wheel contact width (in)	Wheel load (kip)
>	1		16	20
	2	7.5	16	20

Total (for axle): 40.00

New Duplicate Delete

Rating

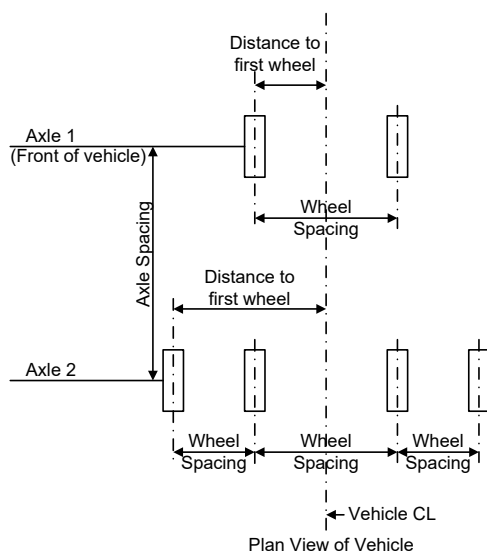
☒ ASR/LFR

☒ LRFR

Save Close

To be able to select this vehicle in the Analysis Settings window when doing a rating, be sure to check the rating boxes.

When describing the axes, 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.



DF1 - Distribution Factor Analysis (NSG - LFR) Example

The description of the wheels in the second axle of the vehicle is shown below.

Vehicle: Non-Standard Gage: New Item

Name: NSG Truck

Description:

Store units as
☒ US
☐ SI

Library
☐ Standard
☒ Agency defined
☐ User defined

Description

Axles

	Axle	Distance to first wheel (ft)	Axle spacing (ft)	Total axle load (kip)
	1	-3.75		40
>	2	-6.25	12	48

Totals: 12.00 88.00

New Duplicate Delete

Wheels

Axle: 2

	Wheel	Wheel spacing (ft)	Wheel contact width (in)	Wheel load (kip)
>	1		16	12
	2	2.5	16	12
	3	7.5	16	12
	4	2.5	16	12

Total (for axle): 48.00

New Duplicate Delete

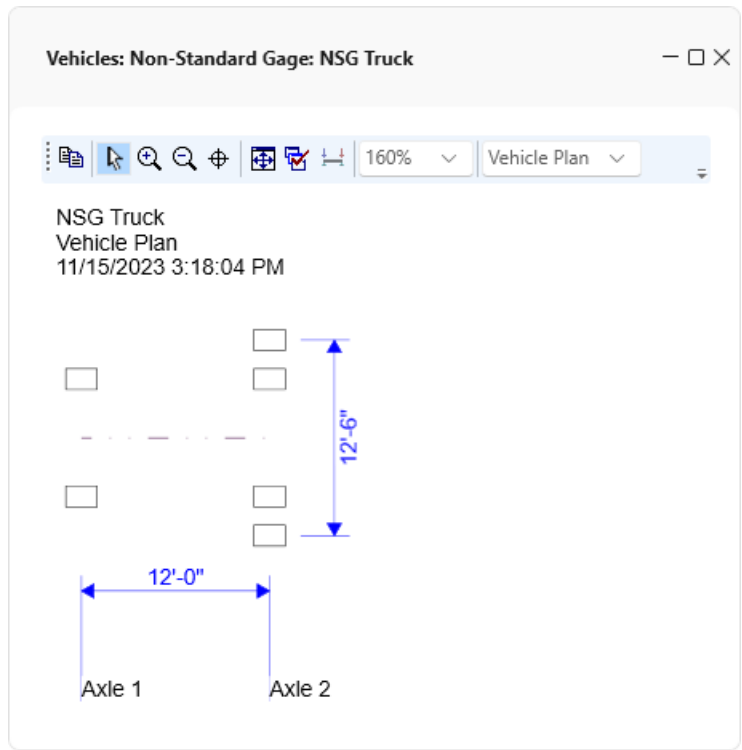
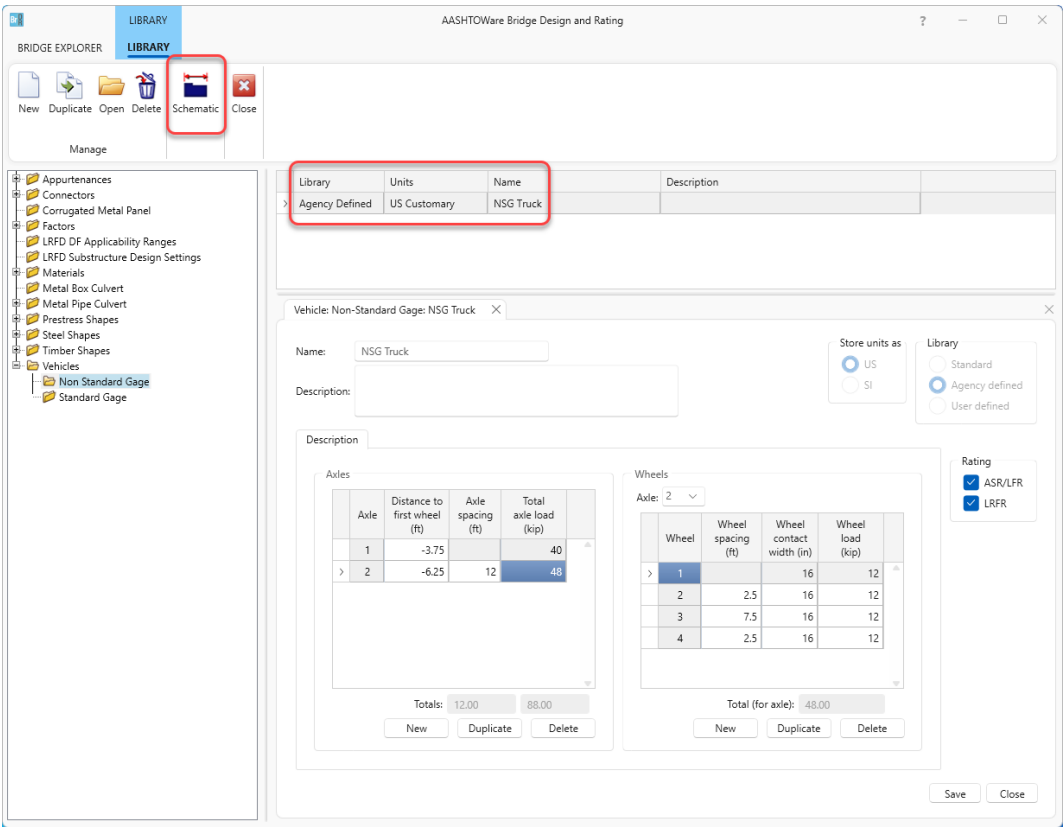
Rating
☒ ASR/LFR
☒ LRFR

Save Close

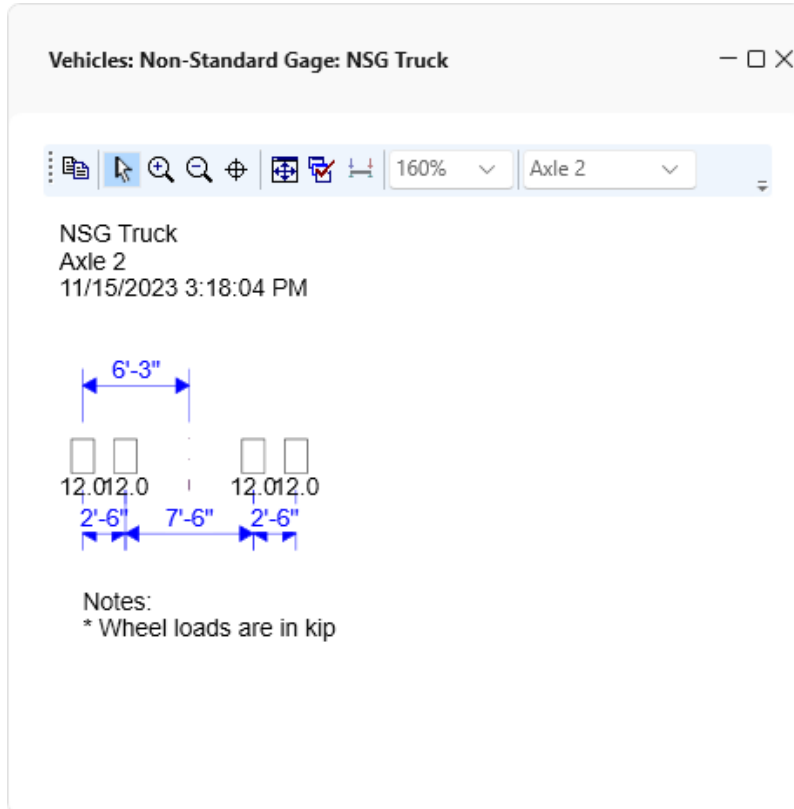
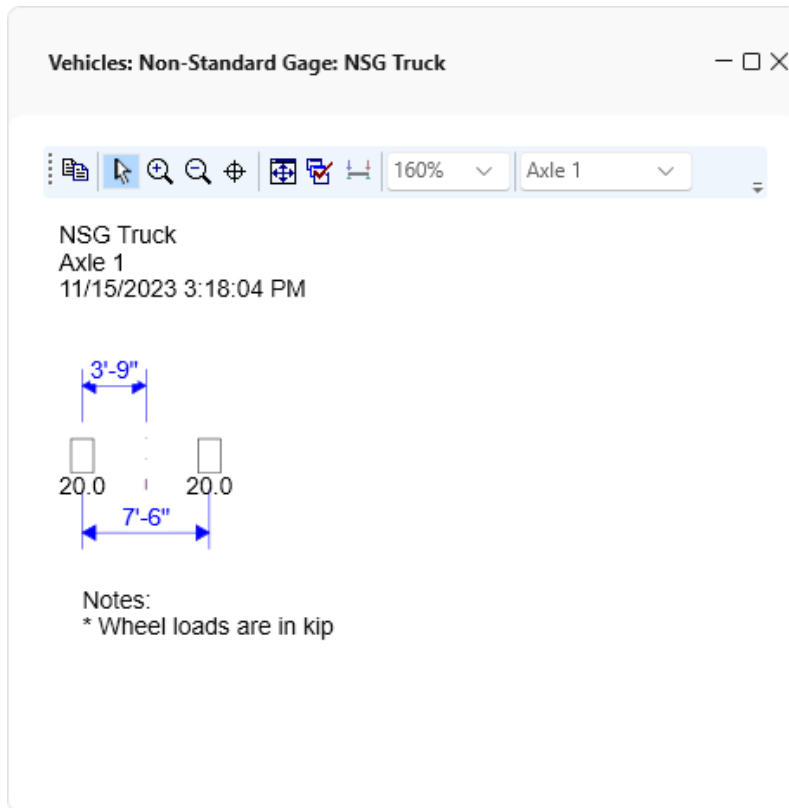
Click **Save** to save this vehicle to the library.

DF1 - Distribution Factor Analysis (NSG - LFR) Example

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.



DF1 - Distribution Factor Analysis (NSG - LFR) Example

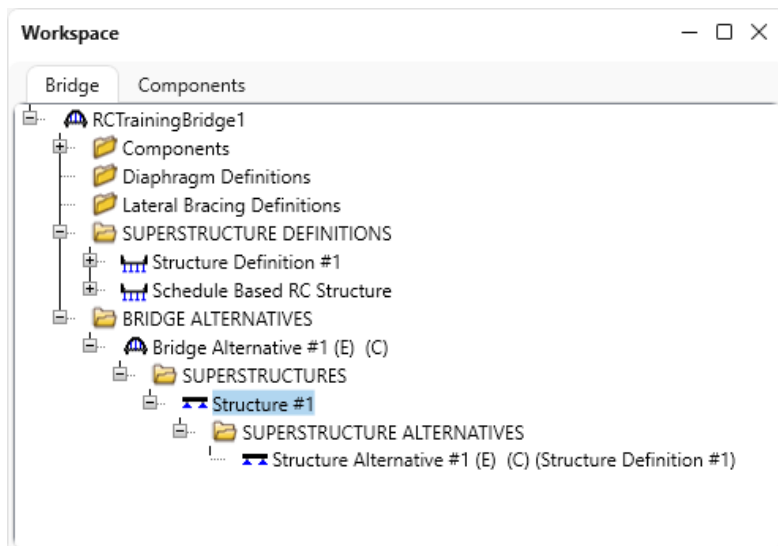
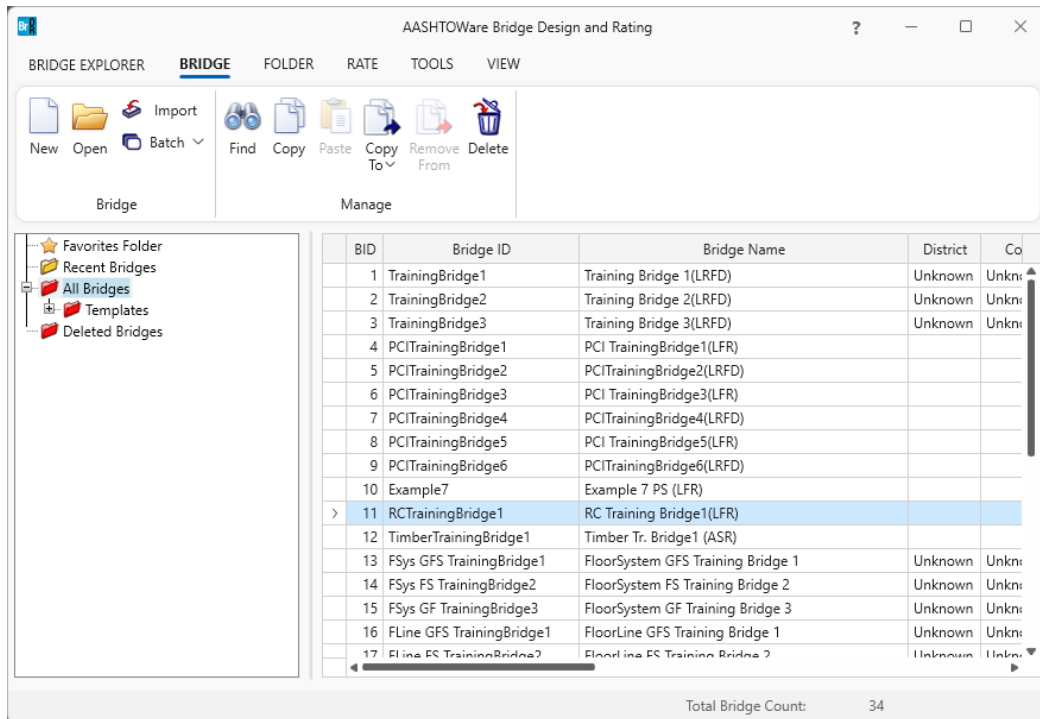


DF1 - Distribution Factor Analysis (NSG - LFR) Example

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, **BID11 (RCTrainingBridge1)** in the **BrDR sample database** will be analyzed. Open the **Bridge Workspace** for **BID11**. The partially expanded **Bridge Workspace** for **BID11** is shown below. The distribution factor analysis for **Structure #1** will perform a 3D and Line Girder analyses of the **Structure Definition #1** which is assigned to the existing superstructure alternative.



DF1 - Distribution Factor Analysis (NSG - LFR) Example

Double click on the **Structure #1** superstructure window and navigate to the **Vehicle path** tab.

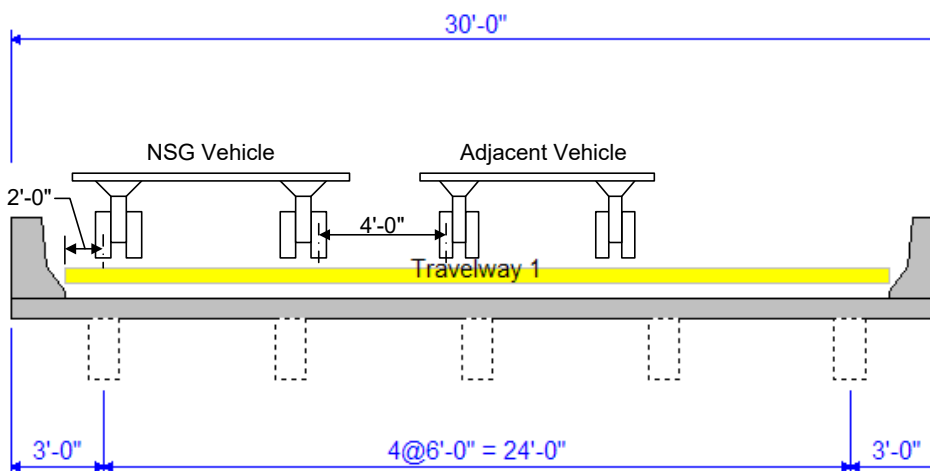
The screenshot shows the 'Superstructure' window with the 'Vehicle path' tab selected. The 'Superstructure name' is 'Structure #1'. The 'Vehicle longitudinal increment' is set to 4 ft. Below this is a table for 'Non-standard gage vehicle path'.

Path	NSG vehicle path type	NSG vehicle distance from left edge of deck (ft)	Adjacent vehicle path type	Adjacent vehicle distance from left edge of deck (ft)
> 1	Centered		None	

Buttons at the bottom include 'New', 'Duplicate', 'Delete', 'OK', 'Apply', and 'Cancel'.

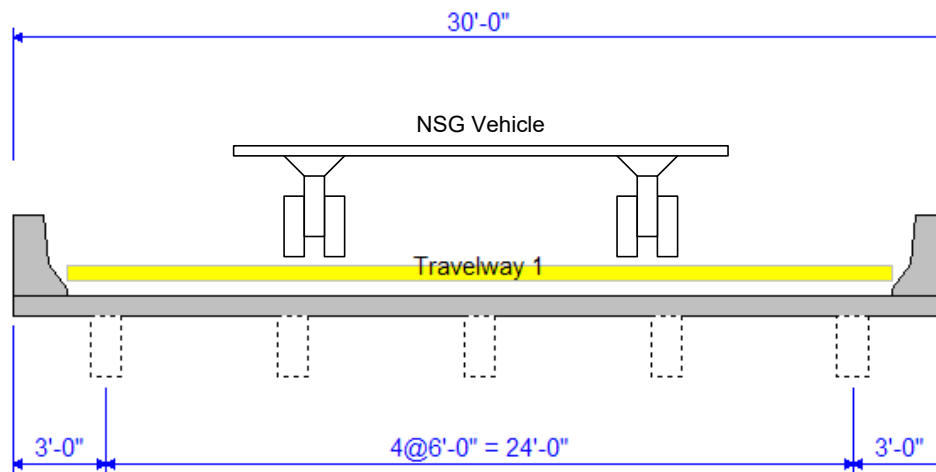
This tab controls the placement of the vehicle that will be used in the distribution factor analysis. The **Vehicle longitudinal increment** is the longitudinal length increment to use when moving the vehicle along the length of the superstructure. Note that this value can greatly affect the time required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



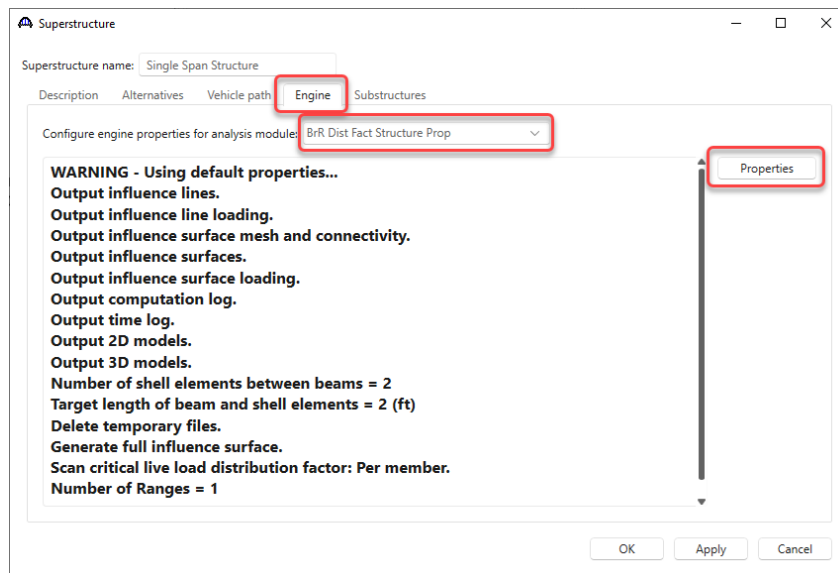
DF1 - Distribution Factor Analysis (NSG - LFR) Example

This example uses the **NSG vehicle path** specified as **Centered** and the **Adjacent vehicle path** as **None**. This path is shown below.



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.



DF1 - Distribution Factor Analysis (NSG - LFR) Example

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

The screenshot shows the 'Analysis' tab of the 'BrR Dist Fact Superstructure Properties' window. It contains several configuration sections:

- Output Control:** A list of checkboxes, all of which are checked: Influence lines, Influence line loading, Influence surface mesh and connectivity, Influence surfaces, Influence surface loading, Computation log, Time log, 2D models, and 3D models.
- Number of shell elements between beams:** A slider ranging from 1 to 6. The slider is positioned at 2, with labels 'Slower More accurate' on the left and 'Faster Less accurate' on the right.
- Target length of beam and shell elements:** A slider ranging from 0.5 to 4 feet. The slider is positioned at 2, with labels 'Slower More accurate' on the left and 'Faster Less accurate' on the right.
- Influence Surface Control:** Two radio buttons: 'Generate full influence surface' (unselected) and 'Generate path influence surface' (selected). A checkbox for 'Delete temporary files' is also checked.
- Distribution Factor Engine Option:** A dropdown menu set to 'Per member' and a text input field for 'Number of ranges' containing the value '1'.

At the bottom right of the window are 'OK' and 'Cancel' buttons.

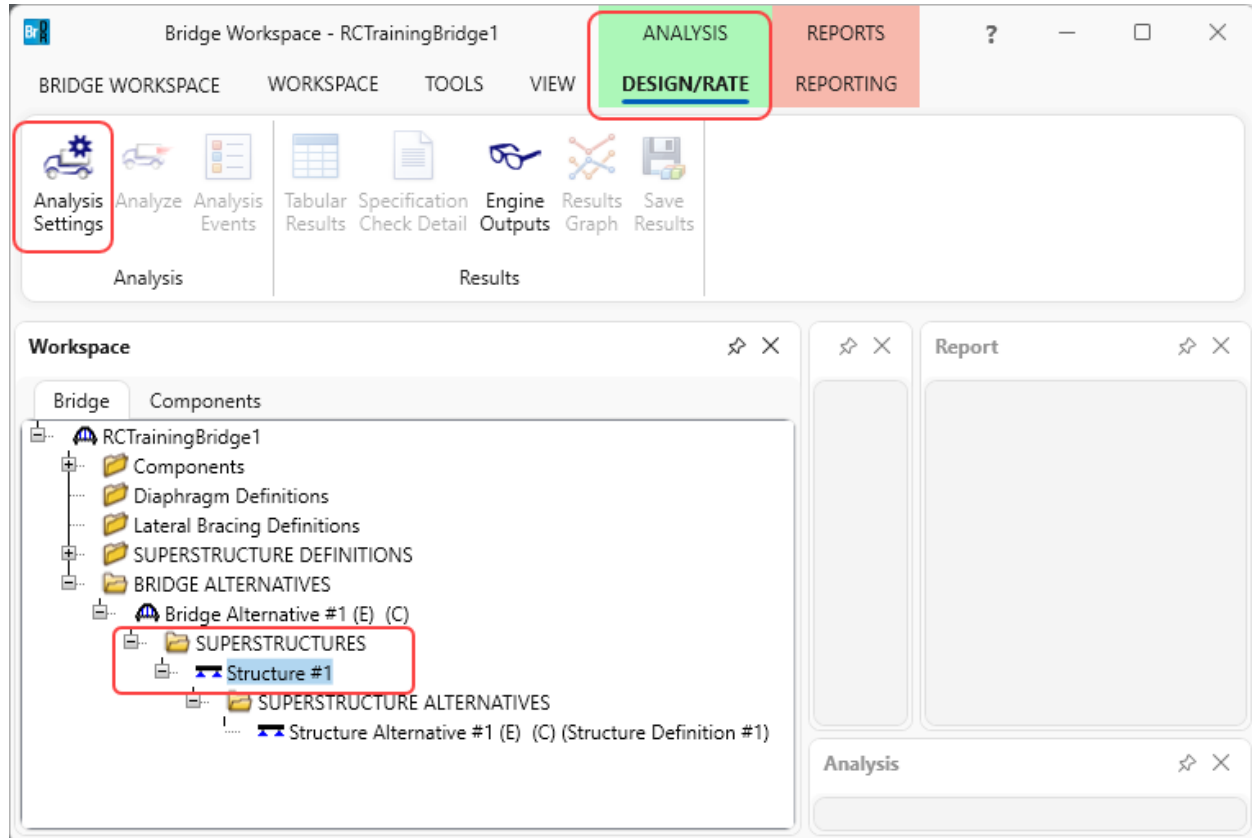
Select **Generate path influence surface** under **Influence Surface Control**. The **Scan critical live load distribution factor** selection allows to specify the method for determining the critical distribution factors. The **Per member** option specifies one critical moment and one critical shear 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.

DF1 - Distribution Factor Analysis (NSG - LFR) Example

Perform Distribution Factor Analysis (NSG - LFR)

The distribution factor analysis can be initiated by selecting the **Structure #1** superstructure in the **Bridge Workspace** tree and clicking the **Analysis Settings** button in the **Analysis** Group of the **DESIGN/RATE** ribbon.



DF1 - Distribution Factor Analysis (NSG - LFR) Example

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.

Analysis Settings

☐ Design review ☒ Rating

Rating method: LFR

Analysis type: Dist Factor-Line Girder

Lane / Impact loading type: As Requested

Apply preference setting: None

Vehicles | Output | Engine | Description

Traffic direction: Both directions

Vehicle selection

- Vehicles
 - Standard gage vehicles
 - Standard
 - Alternate Military Loading
 - EV2
 - EV3
 - H 15-44
 - H 20-44
 - HS 15-44
 - HS 20 (SI)
 - HS 20-44
 - NRL
 - SU4
 - SU5
 - SU6
 - SU7
 - Type 3
 - Type 3-3
 - Type 3S2
 - Agency
 - User defined
 - Temporary
 - Non-standard gage vehicles
 - Agency
 - NSG Truck
 - User defined
 - Temporary

Add to >>

Remove from <<

Vehicle summary

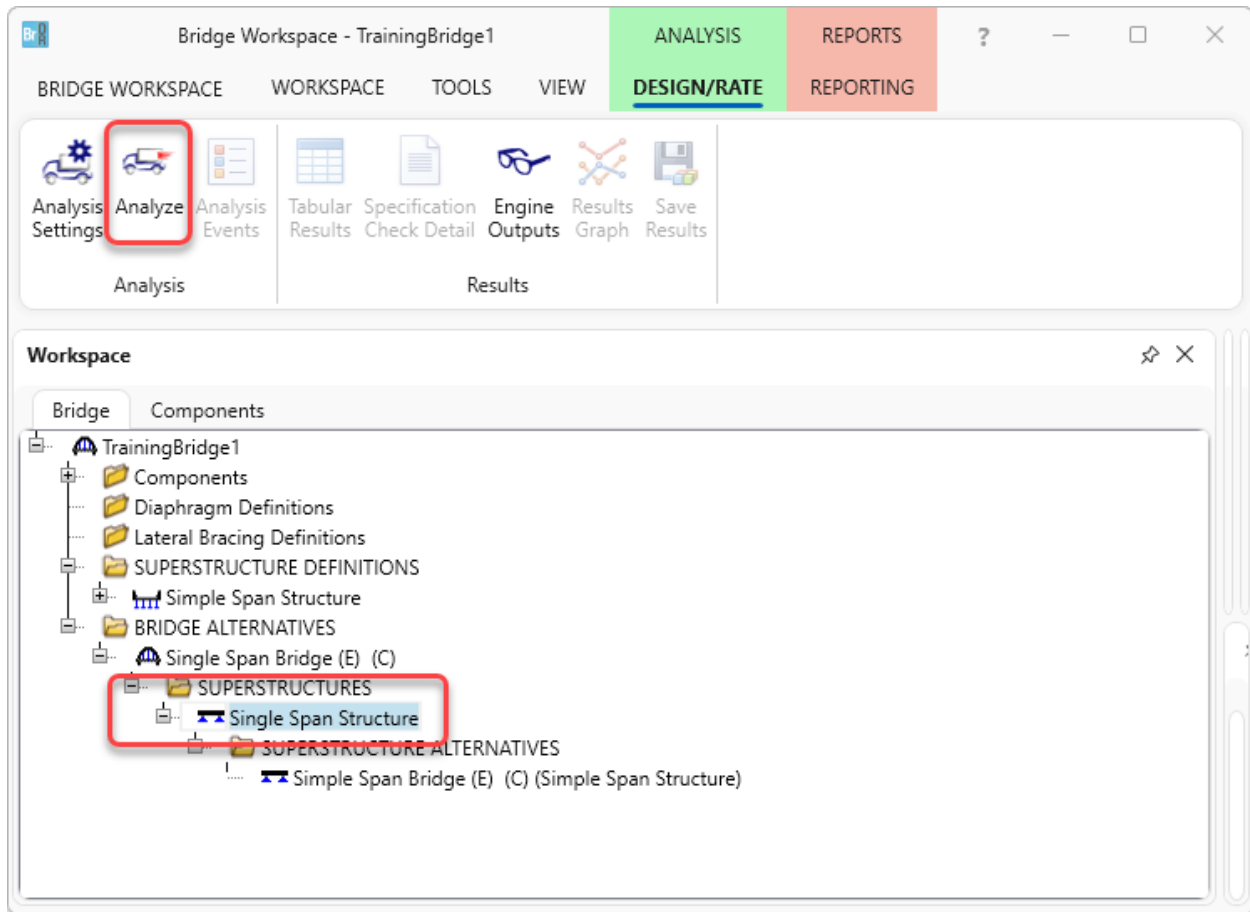
- Rating vehicles
 - Inventory
 - NSG Truck
 - Adjacent lane vehicle
 - Operating
 - NSG Truck
 - Adjacent lane vehicle

Reset Clear Open template Save template OK Apply Cancel

Click **OK** to apply the analysis settings and close the window.

DF1 - Distribution Factor Analysis (NSG - LFR) Example

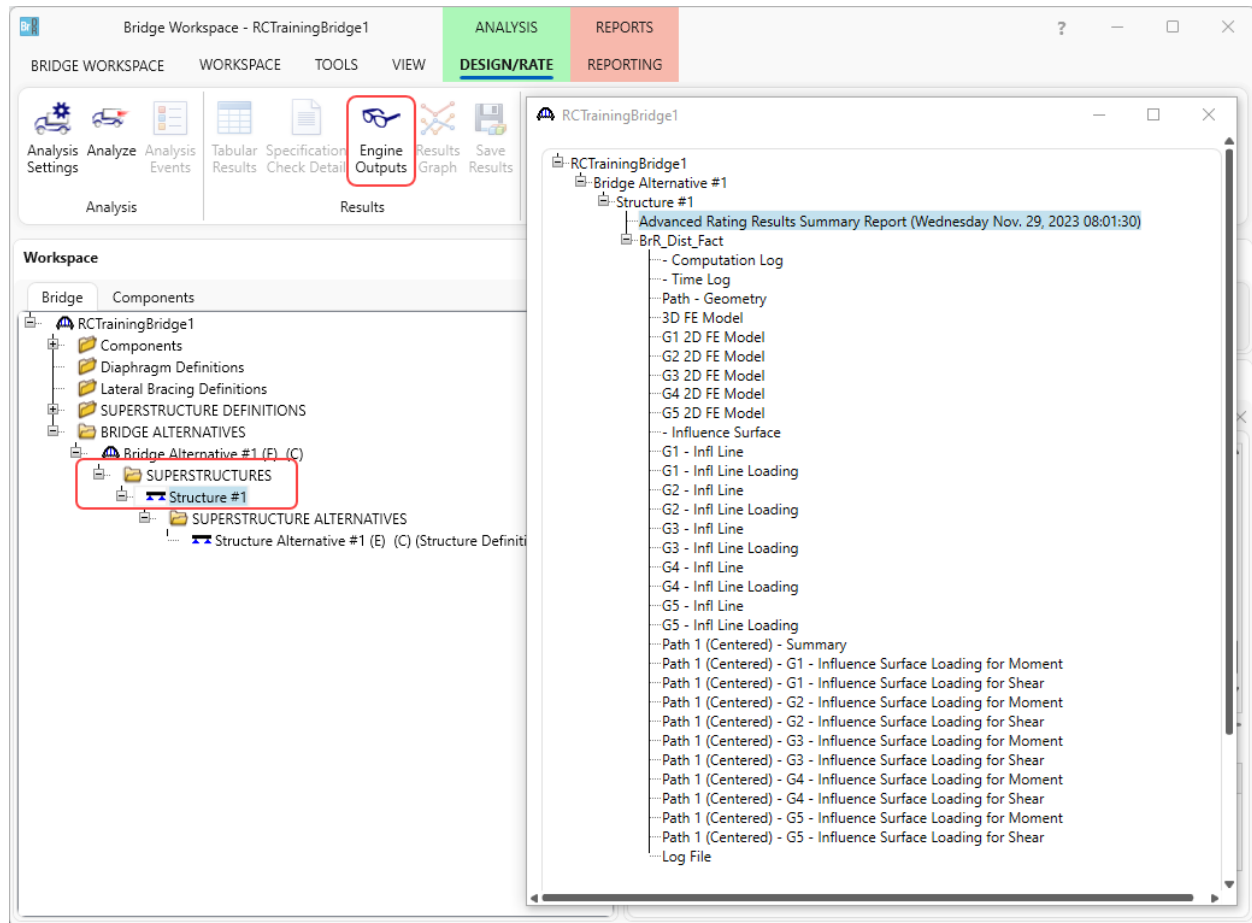
Click the **Analyze** button in the **Analysis** Group of the ribbon to initiate the Distribution Factor-Line Girder analysis.



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.

DF1 - Distribution Factor Analysis (NSG - LFR) Example

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 Line Girder finite element models, the influence surface and influence lines and their loading.

DF1 - Distribution Factor Analysis (NSG - LFR) Example

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.

<div> <div>Advanced Rating Results Summary Report</div> <div> <div></div> <div></div> <div></div> </div> </div>									
<p> Bridge Name: RC Training Bridge1(LFR) Bridge ID: 11 Super Structure: Structure #1 </p> <p> Analysis Date: Wednesday, November 29, 2023 08:01:19 </p> <p> Inventory Vehicle: NSG Truck Adjacent Inventory Vehicle: </p> <p> Operating Vehicle: NSG Truck Adjacent Operating Vehicle: </p> <p> Loading Path: NSG (Centered) - ADJ (None) </p>									
Member	Inventory Capacity (Ton)	Operating Capacity (Ton)	Inventory Location / Element Name (ft)	Operating Location / Element Name (ft)	Inventory Rating Factor	Operating Rating Factor	Inventory Limit State	Operating Limit State	Success / Failure
G1	104.80	175.02	20.000 (1 - 50.00%)	20.000 (1 - 50.00%)	2.382	3.978	Design Flexure - Concrete	Design Flexure - Concrete	Success
G2	66.84	111.62	20.000 (1 - 50.00%)	20.000 (1 - 50.00%)	1.519	2.537	Design Flexure - Concrete	Design Flexure - Concrete	Success
G3	60.36	100.80	20.000 (1 - 50.00%)	20.000 (1 - 50.00%)	1.372	2.291	Design Flexure - Concrete	Design Flexure - Concrete	Success
G4	66.84	111.62	20.000 (1 - 50.00%)	20.000 (1 - 50.00%)	1.519	2.537	Design Flexure - Concrete	Design Flexure - Concrete	Success
G5	104.80	175.02	20.000 (1 - 50.00%)	20.000 (1 - 50.00%)	2.382	3.978	Design Flexure - Concrete	Design Flexure - Concrete	Success

Member	Start Range (ft)	End Range (ft)	Moment Dist. Factor (Lanes)	Shear Dist. Factor (Lanes)
G1	0.000	40.000	0.128	0.070
G2	0.000	40.000	0.245	0.348
G3	0.000	40.000	0.272	0.361
G4	0.000	40.000	0.245	0.348
G5	0.000	40.000	0.128	0.070

DF1 - Distribution Factor Analysis (NSG - LFR) Example

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.

