AASHTOWare BrDR 7.5.0 Distribution Factor-Line Girder Analysis Tutorial DF2 – Distribution Factor Analysis (NSG - LFR) Example

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- Review Distribution Factor Analysis
  - o 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 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 non-standard gage vehicles.

A 3D and a 2D 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 2D finite element analysis is then performed for each beam. The 2D FE model consists of the beam modeled as frame elements. The nodes in the 2D 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 2D 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.

Moment and shear distribution factors are computed by dividing the 3D model moments and shears by the 2D 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 E	Data
Front Axle	Load/Axle Line	40 kips
	Load/Tire	20 kips
	Load/Axle Line	48 kips
Real Axie	Load/Tire	12 kips
Total Vehic	cle Weight	88 kips



**End View of Front Axle** 



End View of Rear Axle

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.

BrB		AASHT	FOWare B	ridge Desig	n and Rating	?	- 0	$\times$
BRIDGE EXPLORE	R BRIDGE	FOLDER	RATE	TOOLS	VIEW			
Refresh Retr	ieve All 🗱 ieve Next 🗱	Select All Select None Invert Selectio	Sort By~	Select Columns	US Customary \vee	Library	Configuration	
		Bridge Explor	rer View		Tatal Daidan Caust	22		

Br	LIBRARY			AASHTOWare	Bridge Design and Ratin	g	?	_	×
BRIDGE EXPLORER	en Delete	Schematic Close							
Connectors     Corrugated Met     Corrugated Met     Factors     LRFD DF Applica     LRFD Substructt     Materials     Metal Box Culve     Metal Box Culve     Steel Shapes     Steel Shapes     Vehicles     Non Standar     Standard Ga	al Panel ability Range ure Design S ert ert s d Gage ge	.s ettings	Library	Units	Name	Description			

#### DF2 - Distribution Factor Analysis (NSG - LFR) Example

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

ne:		NSG	Truck								Store uni	its as	Library
crip	tion										SI		Agency defined
esc	riptio Axles	n					Whee	els					Rating
		Axle	Distance to first wheel	Axle spacing	Total axle load		Axle:	1 ~					LRFR
			(ft)	(ft)	(kip)			Wheel	Wheel spacing	Wheel contact	Wheel load		<b>†</b>
		1	-3.75		40				(ft)	width (in)	(kip)		
	>	2	-6.25	12	0		>	1		16	20		
								2	7.5	16	20	Ŧ	To be able t select this vehicle in th Analysis Settings window whe
			Totals:	12.00	40.00				Total (fo	or axle): 40.0	0		doing a ratin be sure to
			New	Duplic	ate De	lete			New	Duplicate	e Dele	te	check the rating boxe

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.



## DF2 - Distribution Factor Analysis (NSG - LFR) Example

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

											C Store uni	its as	Library
me:		NSG	Truck								O us		Standard
	-										i si		O Agency defined
script	tion:												User defined
		_											
Descr	iptic	on											
- A	xles						Whe	els					Rating
			D'		<b>T</b>		Axle	2 ~					ASR/LFF
		Axle	first wheel	spacing	axle load			•					LRFR
			(ft)	(ft)	(kip)			Wheel	Wheel spacing	Wheel contact	Wheel load		
		1	-3.75		40				(ft)	width (in)	(kip)		
	>	2	-6.25	12	48		>	1		16	12	-	
								2	2.5	16	12		
								3	7.5	16	12		
								4	2.5	16	12		
						w.						w	
			Totals:	12.00	88.00				Total (fo	or axle): 48.0	0		
			New	Duplic	ate Del	ete		(	New	Duplicate	e Delet	te	

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.

BRIDGE EXPLORER LIBRARY	AASHTOWare Bridge Design and Rating	? – 🗆 X
New Duplicate Open Delete Schematic		
Manage	Library         Units         Name         Description           Agency Defined         US Customary         NSG Truck	
Image: Performance of the second	Vehicle: Non-Standard Gage: NSG Truck     X       Name:     NSG Truck       Description:     US       Store     SI	X Library Standard Agency defined User defined
	Asies         Wheels           1         -3.75         40           2         -6.25         12         48	Rating ASR/LFR RFR LRFR
	Totals: 12.00 88.00 New Duplicate Delete New Duplicate Delete	Save Close

Vehicles: Non-Standard Gage: NSG Truck	- 🗆 ×
🗈 🕞 🕄 🕂 🗃 🗟 🖂 160% 🗸 Vehicle Plan 🗸	÷
NSG Truck Vehicle Plan 11/15/2023 3:18:04 PM	
<b>↓ 12'-0"</b>	
Axle 1 Axle 2	



Vehicles: Non-Standard Gage: NSG Truck	- o ×
🖻 🔖 🔍 🔍 🕂 🔠 🔂 🖂 160% 🗸 🗸 Axle 2 🗸	÷
NSG Truck Axle 2 11/15/2023 3:18:04 PM	
6'-3" 12.012.0 2'-6" 7'-6" 2'-6" 12.012.0	
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 2D 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.

Supe	erstru	ucture						-		×
uperst	ructu	ure nan	ne: Single Spar	Vehicle path	ine Subs	tructures				
Veh	icle l	longitu	dinal increment:	4 ft	ine 3003	ductores				
		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 $\checkmark$		None \vee		₽		-	
									v	
							New Duplicate	Dele	ete	
							ОК Арр	ly	Cano	el

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.



# BrDR Distribution Factor Engine Properties

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

A Superstructure	– 🗆 X
<ul> <li>Superstructure</li> <li>Superstructure name: Single Span Structure</li> <li>Description Alternatives Vehicle path Engine Substructures</li> <li>Configure engine properties for analysis module: BrR Dist Fact Structure Prop </li> <li>WARNING - Using default properties</li> <li>Output influence lines.</li> <li>Output influence line loading.</li> <li>Output influence surface mesh and connectivity.</li> <li>Output influence surfaces.</li> <li>Output influence surface loading.</li> <li>Output computation log.</li> <li>Output 2D models.</li> <li>Output 3D models.</li> <li>Number of shell elements between beams = 2</li> <li>Target length of beam and shell elements = 2 (ft)</li> <li>Delete temporary files.</li> <li>Generate full influence surface.</li> <li>Scan critical live load distribution factor: Per member.</li> <li>Number of Ranges = 1</li> </ul>	Properties
	OK Apply Cancel

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

alysis											
Output Control			Number	of shell el	ements	between b	eams				
✓ Influence lines			Slower						Faster		
Influence line loading			More ac	urate					Less acci	urate	
Influence surface mesh and connectiv	/ity		6	5		4	3	0	2	1	
Influence surfaces											
Influence surface loading			Target lei	ngth of be	eam and	shell elem	ients				
Computation log			Slower						Faster		
✓ Time log			More ac	urate					Less acci	urate	
✓ 2D models			0.5	1	1.5	2 (ft)	2.5	3	3.5	4	
✓ 3D models											
Influence Surface Control											
Generate full influence surface			Delete t	emporary	files						
O Generate path influence surface											
Distribution Factor Engine Option											
Scan critical live load distribution factor:	Per member	$\sim$									
Number of ranges:	1										

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 – LFR)

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.

BRIDGE WORKSPACE	rkspace - TrainingBr WORKSPACE T(	idge1	ANALY: DESIGN/	SIS RATE	REPORTS		?	_	×
Analysis Settings Analysis Analysis	Tabular Specificat Results Check De	ion Engine R tail Outputs (	esults Save Graph Results						
Workspace Bridge Components TrainingBridge1 Components Components Diaphragm Defi Lateral Bracing I SUPERSTRUCTU	nitions Definitions IRE DEFINITIONS Structure		2	< Sc	hematic	\$ X	R	leport	* *
BRIDGE ALTERN	ATIVES Bridge (E) (C) RUCTURES e Span Structure OPERSTRUCTORE A Simple Span Bridg	TERNATIVES ge (E) (C) (Simp	le Span Structu	re)	nalysis				* *

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.

Design review O Rating	Rating method:	
e / Impact loading type: As Requested	Apply preference setting: None	<
Traffic direction: Both directions	Refresh         Temporary vehicles         Advanced	
<ul> <li>Vehicles</li> <li>Standard gage vehicles</li> <li>Standard</li> <li>Alternate Military Loading</li> <li>EV2</li> <li>EV3</li> <li>H 15-44</li> <li>H 20-44</li> <li>HS 15-44</li> <li>HS 20-44</li> <li>NRL</li> <li>SU4</li> <li>SU5</li> <li>SU6</li> <li>SU7</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.3</li> <li>Type 3.2</li> <li>Agency</li> <li>User defined</li> <li>Temporary</li> </ul>	Add to	

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

### DF2 - Distribution Factor Analysis (NSG - LFR) Example

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

Bridge Wo	rkspace - TrainingBri	dge1	ANALYSIS	REPORTS	?	_	$\times$
BRIDGE WORKSPACE	WORKSPACE TC	OLS VIEW	DESIGN/RATE	REPORTING			
Analysis Settings	Tabular Specificati Results Check Det	on Engine Res ail Outputs Gra	ults Save ph Results				
Analysis		Results					
Workspace							\$ <
Bridge Components	nitions Definitions IRE DEFINITIONS I Structure ATIVES Bridge (E) (C) RUCTURES e Span Structure OPERSTRUCTURE AL Simple Span Bridg	TERNATIVES e (E) (C) (Simple	Span Structure)				

The **Analysis Progress** window will show the progress of the 3D and 2D 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 2D 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.

dge Name dge ID: 1	e: Training Brid	ige 1(LRFD)									
per Struct	ure: Single Sp	an Structure									
alysis Dat	te: Wednesday	, November	29, 2023 08:37:46								
ventory Ve ljacent Inv	ehicle: NSG T rentory Vehic	ruck le:									
perating V	ehicle: NSG 1	ruck									
цасен Ор	erating venic	ie.									
oading Pa	ath: NSG (C	Centered) -	ADJ (None)								
	Inventory Capacity	Operating Capacity	Inventory Location / Elemen	Oper nt Location	ating / Element e (ft)	Inventory Rating Factor	Operating Rating Factor	Inventory Limit State	Operating Limit State	Success / Failure	
Member	(Ton)	(Ton)	Name (ft)	Inam							
Member G1	(Ton) 268.69	(Ton) 448.72	Name (ff) 80.500 (1 - 50.009	6) 80.500 (1	- 50.00%)	6.107	10.198	Service - Steel	Service - Steel	Success	
Member G1 G2	(Ton) 268.69 117.30	(Ton) 448.72 195.88	Name (ff) 80.500 (1 - 50.009 96.600 (1 - 60.009	6) 80.500 (1 6) 96.600 (1	- 50.00%) - 60.00%)	6.107 2.666	10.198 4.452	Service - Steel Design Shear - Steel	Service - Steel Design Shear - Steel	Success Success	
Member G1 G2 G3	(Ton) 268.69 117.30 118.41	(Ton) 448.72 195.88 197.74	Name (ff)           80.500 (1 - 50.009           96.600 (1 - 60.009           64.400 (1 - 40.009	Number           6)         80.500 (1           6)         96.600 (1           6)         64.400 (1	- 50.00%) - 60.00%) - 40.00%)	6.107 2.666 2.691	10.198 4.452 4.494	Service - Steel Design Shear - Steel Design Shear - Steel	Service - Steel Design Shear - Steel Design Shear - Steel	Success Success Success	
Member           G1           G2           G3           G4	(Ton) 268.69 117.30 118.41 268.44	(Ton) 448.72 195.88 197.74 448.29	Name (ff)           80.500 (1 - 50.00%)           96.600 (1 - 60.00%)           64.400 (1 - 40.00%)           80.500 (1 - 50.00%)	(a)       80.500 (1)         (b)       96.600 (1)         (c)       64.400 (1)         (c)       80.500 (1)	- 50.00%) - 60.00%) - 40.00%) - 50.00%)	6.107 2.666 2.691 6.101	10.198 4.452 4.494 10.188	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Success Success Success Success	
G1         G2         G3         G4	(Ton) 268.69 117.30 118.41 268.44	(Ton) 448.72 195.88 197.74 448.29	Name (tt)           80.500 (1 - 50.00%)           96.600 (1 - 60.00%)           64.400 (1 - 40.00%)           80.500 (1 - 50.00%)	Name           (a)         80.500 (1)         96.600 (1)         9	- 50.00%) - 60.00%) - 40.00%) - 50.00%)	6.107 2.666 2.691 6.101	10.198           4.452           4.494           10.188	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Success Success Success Success	
Member G1 G2 G3 G4 Member	(Ton) 268.69 117.30 118.41 268.44 Start Ran	(Ton) 448.72 195.88 197.74 448.29 ge (ft) E	Name (tt)           80.500 (1 - 50.00%)           96.600 (1 - 60.00%)           64.400 (1 - 40.00%)           80.500 (1 - 50.00%)           nd Range (ft)           M	Ivam           (a)         80.500 (1)           (b)         96.600 (1)           (a)         64.400 (1)           (b)         80.500 (1)	- 50.00%) - 60.00%) - 40.00%) - 50.00%) Shear D Factor (L:	6.107 2.666 2.691 6.101 Dist. anes)	10.198 4.452 4.494 10.188	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Success Success Success Success	
G1 G2 G3 G4 Member G1	(Ton) 268.69 117.30 118.41 268.44 Start Ran 0.000	(Ton) 448.72 195.88 197.74 448.29 ge (ft) E	Name (tt) 80.500 (1 - 50.009 96.600 (1 - 60.009 64.400 (1 - 40.009 80.500 (1 - 50.009 nd Range (tt) 161.000	(a)         80.500 (1)           (a)         96.600 (1)           (a)         64.400 (1)           (a)         80.500 (1)           (c)         64.400 (1)           (a)         80.500 (1)           (b)         80.500 (1)           (c)         80.500 (1)           (c)         80.500 (1)           (c)         80.500 (1)	- 50.00%) - 60.00%) - 40.00%) - 50.00%) Shear D Factor (L 0.132	6.107 2.666 2.691 6.101 Dist. anes)	10.198 4.452 4.494 10.188	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Success Success Success Success	
Member G1 G2 G3 G4 Member G1 G2	(Ton) 268.69 117.30 118.41 268.44 Start Ram 0.000 0.000	(Ton) 448.72 195.88 197.74 448.29 ge (ft) E	Name (ft)           80.500 (1 - 50.009           96.600 (1 - 60.009           64.400 (1 - 40.009           80.500 (1 - 50.009           and Range (ft)           M           161.000           161.000	0         80.500 (1           0         96.600 (1           0         64.400 (1           0         80.500 (1           0         80.500 (1           0         80.500 (1           0         80.500 (1           0         80.500 (1           0.171         0.324	- 50.00%) - 60.00%) - 40.00%) - 50.00%) - 50.00%) Shear D Factor (L. 0.132 0.512	6.107 2.666 2.691 6.101 Dist. anes) 2 2	10.198 4.452 4.494 10.188	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Success Success Success Success	
Member G1 G2 G3 G4 Member G1 G2 G3	(Ton) 268.69 117.30 118.41 268.44 Start Ram 0.000 0.000 0.000	(Ton) 448.72 195.88 197.74 448.29 ge (ft) E	Name (ft)           80.500 (1 - 50.009           96.600 (1 - 60.009           64.400 (1 - 40.009           80.500 (1 - 50.009           and Range (ft)         M Fa           161.000           161.000           161.000	0         80.500 (1           0         96.600 (1           0         64.400 (1           0         80.500 (1           0         80.500 (1           0         80.500 (1           0         80.500 (1           0         80.500 (1           0.171         0.324           0.323         0.323	- 50.00%) - 60.00%) - 40.00%) - 50.00%) - 50.00%) Shear D Factor (L: 0.132 0.512 0.508	6.107 2.666 2.691 6.101 Vist. anes) 2 2 3	10.198 4.452 4.494 10.188	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Service - Steel Design Shear - Steel Design Shear - Steel Service - Steel	Success Success Success Success	

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.

