Implements of Husbandry (IoH) Load Rating

MnDOT State Aid Bridge Office

2023 MCEA 15th Annual Summer Conference

DEPARTMENT OF TRANSPORTATION

mndot.gov

Agenda

- Background – TKDA's Contract & Specialized Hauling Vehicles (SHVs) and Load Ratings
- Research for IoH Effects on Bridges
- IoH Live Loads
- Load Ratings
- Postings
- State Statutes
- Future Changes

Background – Specialized Hauling Vehicles (SHVs) and Load Ratings

Background - Specialized Hauling Vehicles (SHVs) and Load Ratings

What is an Implement of Husbandry (IoH)?: A self-propelled or towed vehicle designed or adapted to be used exclusively for timber-harvesting, agricultural, horticultural, or livestock-raising operations.

MN Statute 169.011, Subdivision 35

TerraGator

Tractor with one Honey Wagon Tank

Background - Specialized Hauling Vehicles (SHVs) and Load Ratings

- The deterioration of bridges is a prevalent issue in the United States due to overweight loads.
- Implements of Husbandry are of particular interest and have been studied in recent years because of the damage occurring on bridges and roads.

Tractor with two Honey Wagon Tanks

Tractor Grain Wagon

Research for IoH Effects on Bridges

Research for the IoH Effects on Bridges

Background:

- A pooled fund project, “Study of the Impacts of Implements of Husbandry on Bridges” led by the Iowa DOT aims to assess the impact of the IoH on Bridges

  Volume I: Live Load Distribution Factors and Dynamic Load Allowances
  Volume II: Rating and Posting Recommendations
  Volume III: Appendices

- Efforts have produced valuable information, especially as it relates to lateral load distribution
- Project completed using database of manufacturer’s vehicles

Figure 1: Dahlberg

Transportation Pooled Fund Study
https://www.pooledfund.org/Details/Study/460

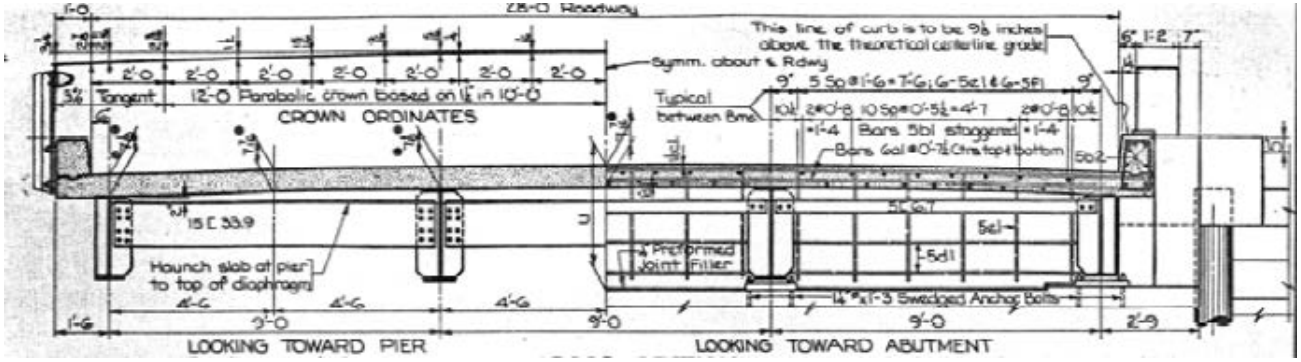
Scope:

- Determine frequency of crossings
- Capture bridge behavior under various dynamic IoH loads
- More closely define the characteristics of husbandry vehicles

Research for the IoH Effects on Bridges

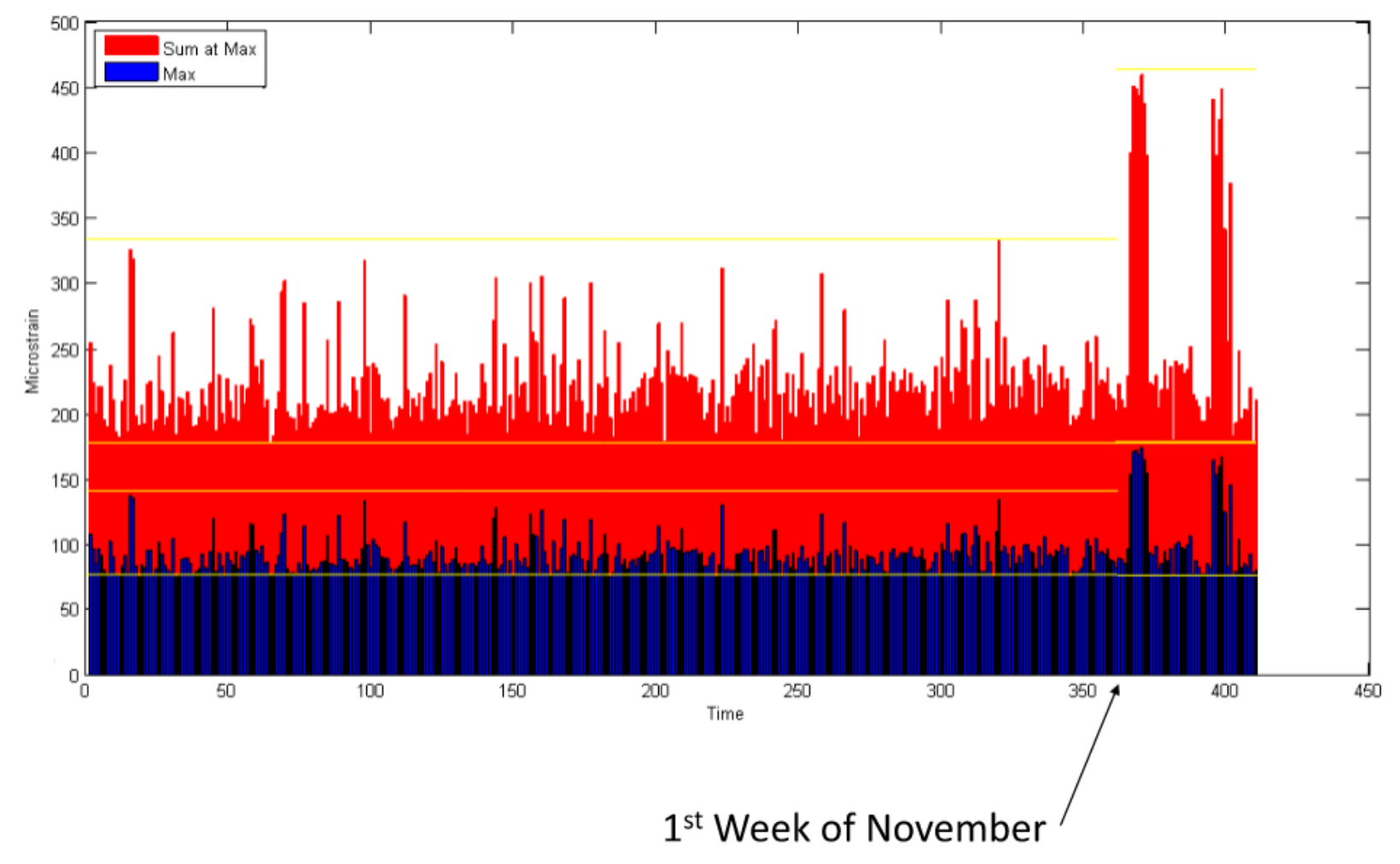
Details of Bridge Studied:

- Simple span I-beam bridge
- 55’ Span
- 28’ roadway
- 4 steel girders and concrete deck
- Timber piles w/ concrete cap
- ADT = 1240



V13-1-64 Iowa DOT Historical Bridge Standard -Constructed in 1967

Research for the IoH Effects on Bridges



Research for the IoH Effects on Bridges

National Cooperative Highway Research (NCHRP 951): Load Rating Provisions for Implements of Husbandry (IoH)

Research for the IoH Effects on Bridges

Background:

- Farm equipment is considered local vehicles on farms
- Growth of IoH has outpaced other legal loads
- Roadway bridge designs are based on AASHTO live load models
- Load ratings based on design live loads

Research Approach:

- Gathered relevant materials and research from the NCHRP
- Developed a set of protocols to evaluate IoH with various configurations for load rating and overload permits
- A survey was created for state, local agencies and farm vehicle manufacturers

Bridge collapse in Illinois caused by a farm vehicle in 2011.

Research for the IoH Effects on Bridges

Identification of Bridges Potentially Impacted Upon by the Load-Rating/Permitting Program:

These features may be potential of vulnerability concern.

1. Older than 30 years of age.
2. Timber primary members.
3. Condition rating at or worse than 5.
4. Narrow width (inadequate for more than one lane).
5. Bridge sites that receive limited or no weight enforcement.
6. Weight posted.

- A mapping tool was created to confirm with Counties on susceptibility to IoH loads.

  https://storymaps.arcgis.com/stories/ca11ecf1f85644d185f1d84afc038832

Research for the IoH Effects on Bridges

Research Findings:

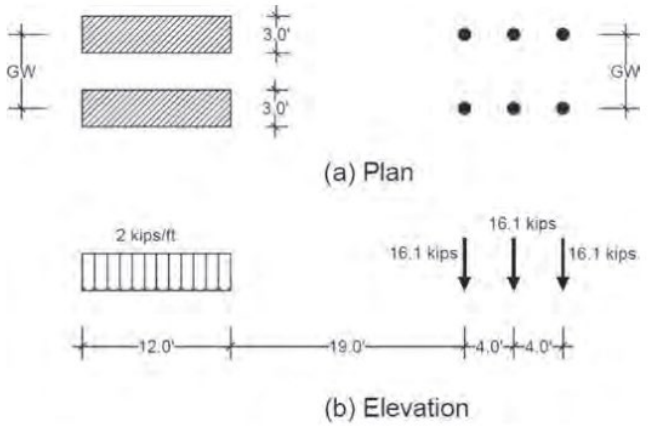
- About 56% of the responding States (22 out of 39) expressed concern with bridge safety related to IoH.
- For most States concerned with IoH loading to bridge safety (19 out of 22 states – 86%) — most bridges of concern are owned by local agencies, such as counties, towns, or municipalities.

Figure 2.1 IoH vehicle observed at Ohio Site No. 38215.

Research for the IoH Effects on Bridges

Key Takeaways:

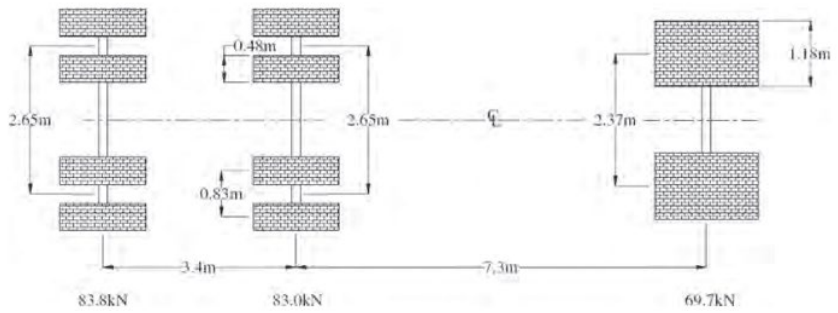
- Load test results show that the dynamic impact of IoH load is lower than the 33% used for bridge design, due to low speed.
- Wider gauge width of IoH results in a lower live load distribution factor and narrower gauge width leads to a higher live load distribution factor.
- Tracked IoH may be modeled conservatively using concentrated wheel or axle loads. A more refined analysis may be performed to reduce conservatism of concentrated loads. See model of tracked IoH to the right:



Research for the IoH Effects on Bridges

Key Takeaways:

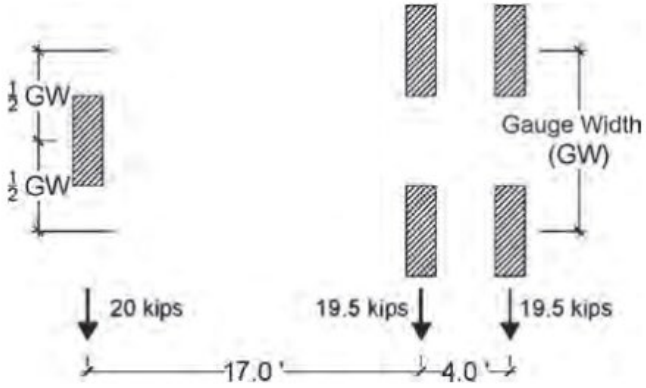
- Dual-tire spread between two tires in one wheel may be neglected up to 2 feet center to center of the two tires. A more refined analysis is needed for larger spreads.



Research for the IoH Effects on Bridges

Key Takeaways:

- Single-tire-steering-axle IoH have a different load distribution from multitier-steering-axle vehicles.



NCHRP-12-110-3: The Guide Manual for Bridge Evaluation for Implements of Husbandry

Research for the IoH Effects on Bridges

Background:

This document aims to serve as a resource for use in developing specific programs, policies and/or procedures for the inspection and evaluation of existing in-service highway bridges regarding Implements of Husbandry (IoH).

Scope:

- Program establishment, inspection, evaluation quality measures and definition of general interest terms.
- Specifications for the load rating of bridges regarding IoH, including the loads and resistance factor method as well as the load factor method.

Research for the IoH Effects on Bridges

Load rating:

Tier 1: Represents the largest portion of IoH, the lowest load-demand among all the tiers.

Tier 1 akin to MN Legal Loads

Tier 2: Represents those IoH heavier than Tier 1 and demanding access to public roads and bridges, if such demand is present and justified.

Tier 2 akin to MN Annual/Routine Permits

Tier 3: Heavier than Tier 2, it is limited to an extremely small number of IoH trips under special circumstances. Escorting maybe needed when taking the trips.

Tier 3 akin to Single Trip Superload Permit Vehicle

IoH Live Loads

IoH Live Loads

IoH Vehicles and Their Model for Bridge Load Rating

One subtask of NCHRP 951 was to develop a model that can envelop the IoH most likely appearing on public roads.

These vehicles were used to develop a **notional model** of IoH for facilitating load rating and possibly permit checking.

Based on the "clustering" of vehicles in the notional model, the loadings from those vehicles were evaluated at the most severe position to generate a **notional load** effect believed to envelop maximum credible load effect.

Here are the notional loads, based on three Tiers:

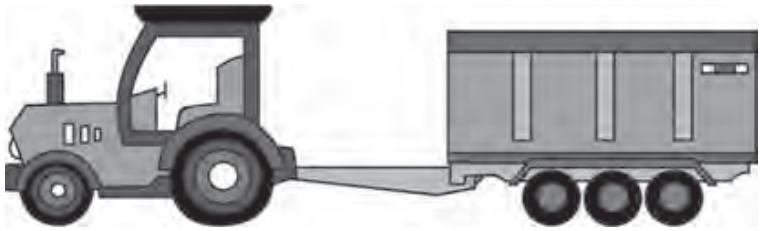
IoH Live Loads

Tier 1 IoH Vehicles

It is recommended to cover a vast majority of IoH vehicles currently demanding having access to public roads and bridges.

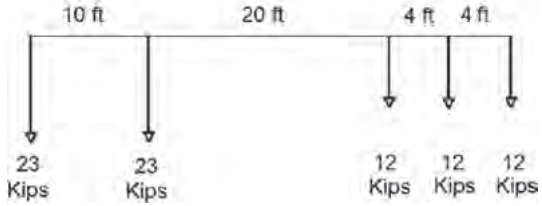
Recommended notional model for IoH loads up to 115% of Federal Bridge Formula (FBF):
(a), (b), or (c), which ever induces maximum load effect; (a) and (b) for dual-wheel-steering-axle IoH, (c) for single-wheel-steering-axle IoH.

Maximum axle load = 23 kips.
Maximum gross vehicle weight = 92 kips.

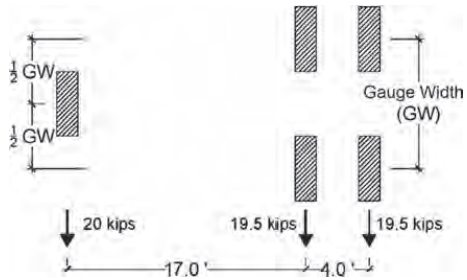


a)

b)



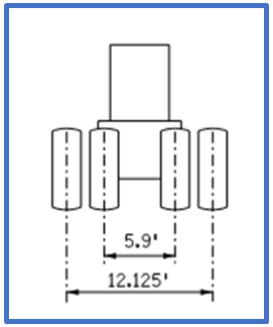
c)



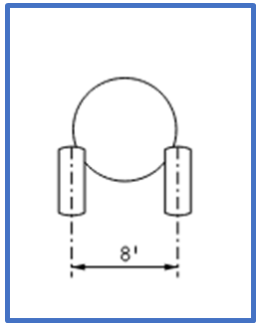
Notice that the Tier 1b vehicle has 23Kip tractor axle loads, which are in excess of MN Statutes. This is the result of considering 115% of the FBF, which the NCHRP reports considered. For the sake of considering the effects of the NCHRP research and reports, this Guide does not lower these loads, however, Tier 1b would require an overload permit.

IoH Live Loads

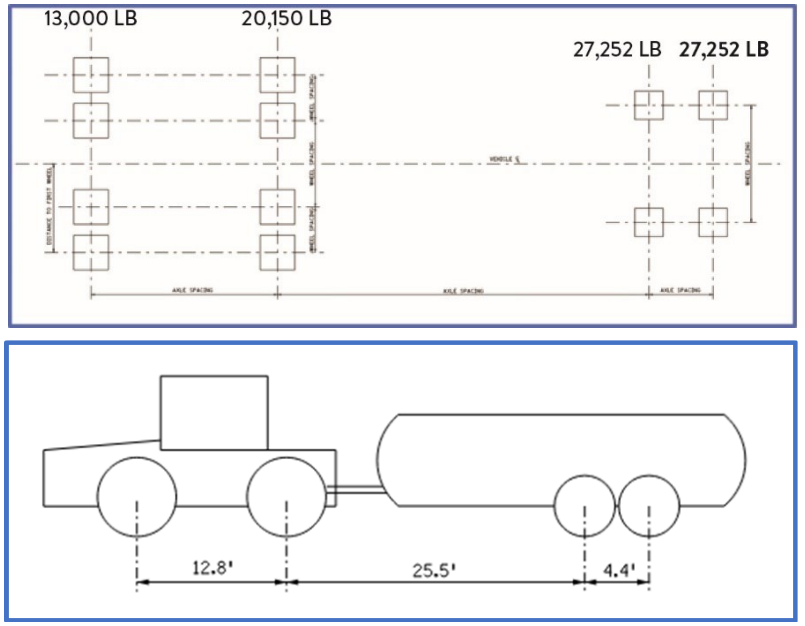
Tier 2 -Non-Standard Vehicle Example
For this specific example, the vehicle is a New Holland T8040 tractor towing a Better-Bilt 4950 manure spreader. This is considered an IoH Tier 2 vehicle. Below is a schematic of the tractor and manure spreader.



End view – New Holland T8040 tractor



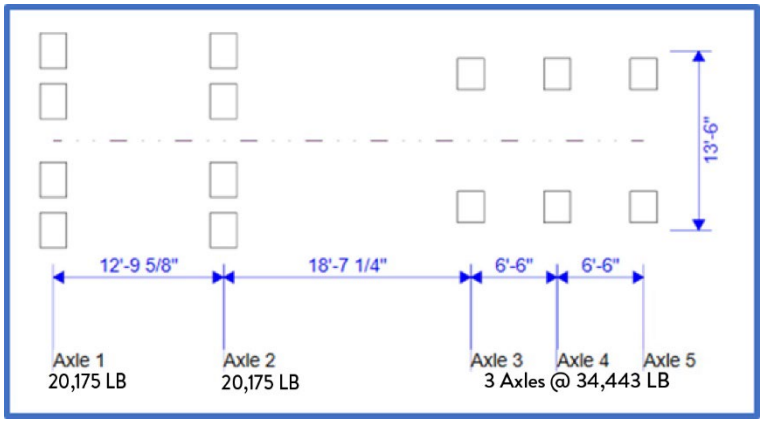
End view- Better-Bilt 4950 manure spreader

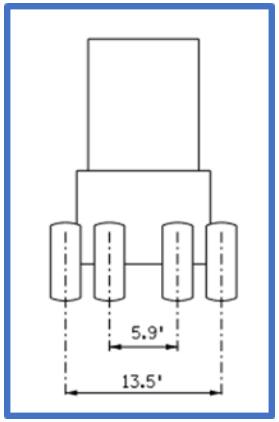


Footprint and Schematic Elevation View of New Holland T8040 tractor towing a Better-Bilt 4950 manure spreader. Total weight of vehicle is 87,754 LB.

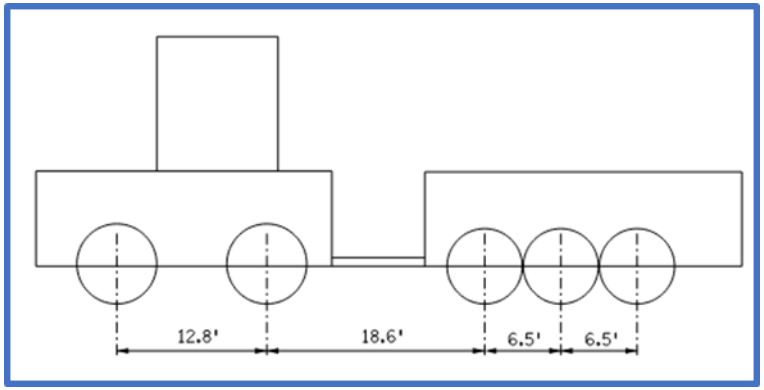
IoH Live Loads

Tier 3 – Non Standard Vehicle Example

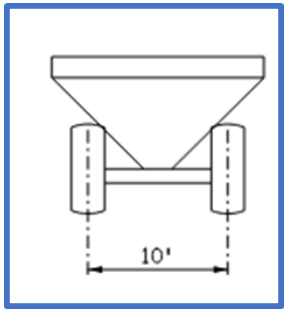




End view-John Deere 9620



Footprint and Schematic Elevation View of John Deere 9620 tractor pulling a Balzer 1500 Grain Cart. Total weight of vehicle is 143,679 LB.



End view- Balzer 1500 Grain Cart

IoH Live Loads

How would a bridge owner know if IoH vehicle is a Tier 1, Tier 2 or Tier 3?

APPENDIX D. FARM IMPLEMENT INVENTORY

This farm vehicle inventory includes 121 farm vehicles and implements that were used in this study. Through internet searches and manufacturer inquiries, information regarding axle weights and configurations was gathered for 121 farm vehicles and implements. These combinations encompassed most combinations seen on US secondary roadway bridges.

The table below summarizes the characteristics of the farm vehicle inventory. The table classifies each vehicle as grain cart or tanker or agricultural truck depending on the use. It also includes the number of axles, axle spacing, and weight of each axle and the spacing between consecutive axles. This information was used to model the vehicular input loads on the finite element models.

Table D-1. Farm vehicle inventory

				1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5
1	Grain Semi	Semi Trailer	4	6.1	6.1	6.1	6.1			17300	17460	16600	16720			4.0	4.0	4.0		
2	John Deere 8520 & Kinze 1050 ROW	Grain Cart	3	7.0	7.0	7.0				11525	11525	73381				9.9	23.9			
3	John Deere 8520 & Houle 3-axle Tank	Manure Tanker	5	7.0	7.0	7.0	7.0	7.0		11525	11525	26600	26600	26600		9.9	14.8	5.7	5.7	
4	John Deere 8520 & Houle 2-axle Tank	Manure Tanker	4	7.0	7.0	7.0	7.0			11525	11525	31290	31290			9.9	17.5	5.7		
5	New Holland TD5050 & Houle 3-axle Tank	Manure Tanker	5	6.6	6.6	7.0	7.0	7.0		8070	8070	26600	26600	26600		7.7	15.0	5.7	5.7	
6	New Holland TD5050 & Houle 2-axle Tank	Manure Tanker	4	6.6	6.6	7.0	7.0			8070	8070	31290	31290			7.7	18.0	5.7		
7	New Holland TD5050 & Kinze 1050 ROW	Grain Cart	3	6.6	6.6	7.0				8070	8070	73381				7.7	24.6			
8	New Holland T4040 & Houle 3-axle Tank		5	5.1	5.1	7.0	7.0	7.0		6724	6724	26600	26600	26600		7.2	15.0	5.7	5.7	
9	New Holland T4040 & Houle 2-axle Tank		4	5.1	5.1	7.0	7.0			6724	6724	31290	31290			7.2	18.0	5.7		
10	New Holland T4040 & Kinze 1050 Row		3	5.1	5.1	7.0				6724	6724	73381				7.2	24.6			
11	John Deere 8520 & Balzer 6350 Narrow	Manure Tanker	4	7.0	7.0	7.3	7.3			11525	11525	36183	36183			9.9	24.3	5.6		
12	New Holland TD5050 & Balzer 6350 Narrow	Manure Tanker	4	6.6	6.6	7.3	7.3			8070	8070	36183	36183			7.7	24.5	5.6		
13	New Holland T4040 & Balzer 6350 Narrow		4	5.1	5.1	7.3	7.3			6724	6724	36183	36183			7.2	24.5	5.6		
14	Terragator 8400	Agricultural Truck	2	7.0	7.5					9338	10758					16.8				
15	John Deere 8520 with Brent 1082 Grain Wagon		3	7.0	7.0	7.8				11525	11525	15660				9.9	23.9			
16	New Holland TD5050 with Grain Wagon	Agricultural Truck	3	6.6	6.6	7.8				8070	8070	15660				7.7	23.9			
17	New Holland T4040 with Grain Wagon		3	5.1	5.1	7.8				6724	6724	15660				7.2	23.9			
18	John Deere 8520 & Better-Bilt 3400	Manure Tanker	4	7.0	7.0	7.9	7.9			11525	11525	18421	18421			9.9	22.7	4.1		
19	New Holland TD5050 & Better-Bilt 3400	Manure Tanker	4	6.6	6.6	7.9	7.9			8070	8070	18421	18421			7.7	23.0	4.1		
20	New Holland T4040 & Better-Bilt 3400		4	5.1	5.1	7.9	7.9			6724	6724	18421	18421			7.2	23.0	4.1		
21	Terragator 7300	Agricultural Truck	2	0.0	8.0					9338	10758					22.8				
22	John Deere 8520 & Kinze 1050 SOF	Grain Cart	3	7.0	7.0	8.0				11525	11525	72101				9.9	23.9			
23	John Deere 8520 & Better-Bilt 4950	Manure Tanker	4	7.0	7.0	8.0	8.0			11525	11525	27252	27252			9.9	25.3	4.4		
24	New Holland TD5050 & Better-Bilt 4950	Manure Tanker	4	6.6	6.6	8.0	8.0			8070	8070	27252	27252			7.7	25.5	4.4		
25	New Holland TD5050 & Kinze 1050 SOF	Grain Cart	3	6.6	6.6	8.0				8070	8070	72101				7.7	24.6			

Load Ratings

Load Ratings

Bulk Review Compared to Existing HL-93 Rating

- Screening Bridge Inventory for Tier 1 IoH Loads
- The notional load presented in the Tier 1 IoH Vehicles is to envelop Tier 1 IoH loads. It can be used to screen bridge inventory against Tier 1 loads without bridge-by-bridge and vehicle-by-vehicle analysis for load rating. This is facilitated by NCHRP 951 Table A-2 that provides ratios of simple span maximum moment of the recommended notional load to other AASHTO legal vehicles and the HL-93.

Ratios of maximum simple span moment of recommended IoH notional load to AASHTO HL93 and legal vehicles.

Span, ft	IoH/ HL93	IoH/ Type3	IoH/ Type3S2	IoH/ Type3-3	IoH /SU4	IoH /SU5	IoH /SU6	IoH /SU7	IoH /NRL
20	0.796	1.285	1.41	1.562	1.104	1.054	1.005	1.005	1.005
21	0.797	1.294	1.42	1.572	1.107	1.047	0.993	0.993	0.993
22	0.798	1.302	1.428	1.582	1.109	1.043	0.981	0.981	0.981
23	0.798	1.309	1.419	1.59	1.113	1.038	0.972	0.968	0.968
24	0.798	1.315	1.404	1.596	1.114	1.034	0.962	0.952	0.952
25	0.797	1.321	1.391	1.603	1.116	1.03	0.956	0.939	0.939
26	0.796	1.324	1.379	1.61	1.118	1.027	0.948	0.926	0.921
27	0.796	1.33	1.368	1.615	1.119	1.024	0.943	0.915	0.903
28	0.794	1.334	1.359	1.619	1.109	1.021	0.937	0.905	0.889
29	0.793	1.338	1.349	1.624	1.098	1.018	0.932	0.896	0.875
30	0.792	1.319	1.341	1.627	1.088	1.016	0.927	0.889	0.863
32	0.789	1.285	1.328	1.586	1.072	1.013	0.919	0.875	0.843
34	0.785	1.258	1.316	1.541	1.058	1.006	0.913	0.863	0.826
36	0.781	1.234	1.307	1.504	1.045	0.989	0.901	0.854	0.809
38	0.777	1.214	1.298	1.472	1.035	0.973	0.886	0.837	0.793
40	0.771	1.197	1.29	1.445	1.026	0.96	0.872	0.821	0.779
42	0.754	1.183	1.284	1.422	1.018	0.949	0.86	0.807	0.767
44	0.736	1.169	1.278	1.401	1.011	0.939	0.85	0.795	0.756
46	0.722	1.161	1.276	1.388	1.008	0.932	0.843	0.786	0.749
48	0.716	1.163	1.285	1.387	1.013	0.934	0.844	0.785	0.749
50	0.71	1.165	1.25	1.385	1.017	0.936	0.845	0.785	0.749
52	0.704	1.167	1.221	1.358	1.022	0.938	0.846	0.784	0.749
54	0.699	1.169	1.195	1.323	1.026	0.939	0.847	0.783	0.749
56	0.694	1.17	1.172	1.292	1.03	0.941	0.847	0.783	0.749
58	0.689	1.171	1.153	1.266	1.033	0.942	0.848	0.782	0.749
60	0.684	1.173	1.135	1.243	1.036	0.943	0.849	0.782	0.749
70	0.701	1.247	1.132	1.211	1.11	1.003	0.901	0.826	0.793
80	0.709	1.303	1.134	1.17	1.167	1.049	0.941	0.86	0.826
90	0.71	1.345	1.135	1.144	1.209	1.083	0.971	0.885	0.851
100	0.707	1.378	1.136	1.126	1.243	1.11	0.994	0.904	0.871
120	0.694	1.426	1.136	1.102	1.292	1.149	1.028	0.933	0.899
140	0.676	1.459	1.137	1.088	1.326	1.176	1.051	0.952	0.919
160	0.657	1.483	1.137	1.078	1.352	1.195	1.069	0.966	0.933
180	0.637	1.501	1.138	1.07	1.371	1.21	1.082	0.977	0.944
200	0.617	1.516	1.138	1.065	1.386	1.222	1.092	0.986	0.952
250	0.571	1.542	1.138	1.055	1.413	1.243	1.11	1.001	0.967
300	0.53	1.559	1.138	1.05	1.432	1.257	1.122	1.011	0.977

Source: NCHRP 951 Table A-2

A simplified example:

- A 48-ft simple bridge span, with a load and resistance factor rating (LRFR) rating factor of 0.94 for its interior beams as primary members, referring to the AASHTO legal load, for which Type 3 controls span moment for rating. Use IM = 20% (instead of 33% for other highway loads) and an MF = 0.85 (15% lower than the AASHTO load and resistance factor design (LRFD) live load distribution factor) deemed to be applicable for the observed gauge widths of IoH in the jurisdiction, the rating for Tier 1 can be estimated as follows for screening purposes.

$$RF_{Tier1IoH} = RF_{Type3}\left(\frac{1}{Table2RatioforIoHoverType3}\right)\left(\frac{1+IM_{HighwayLoad}}{1+IM_{IoH}}\right)\left(\frac{1}{MF}\right)$$

$$= 0.94\left(\frac{1}{1.163}\right)\left(\frac{1.33}{1.20}\right)\left(\frac{1}{0.85}\right)$$

$$= 1.05$$

- If the Rating Factor is less than 1.00 for any particular bridge, a more refined load rating analysis is required. AASHTOWare BrR software can accommodate analysis of most bridges and vehicles.

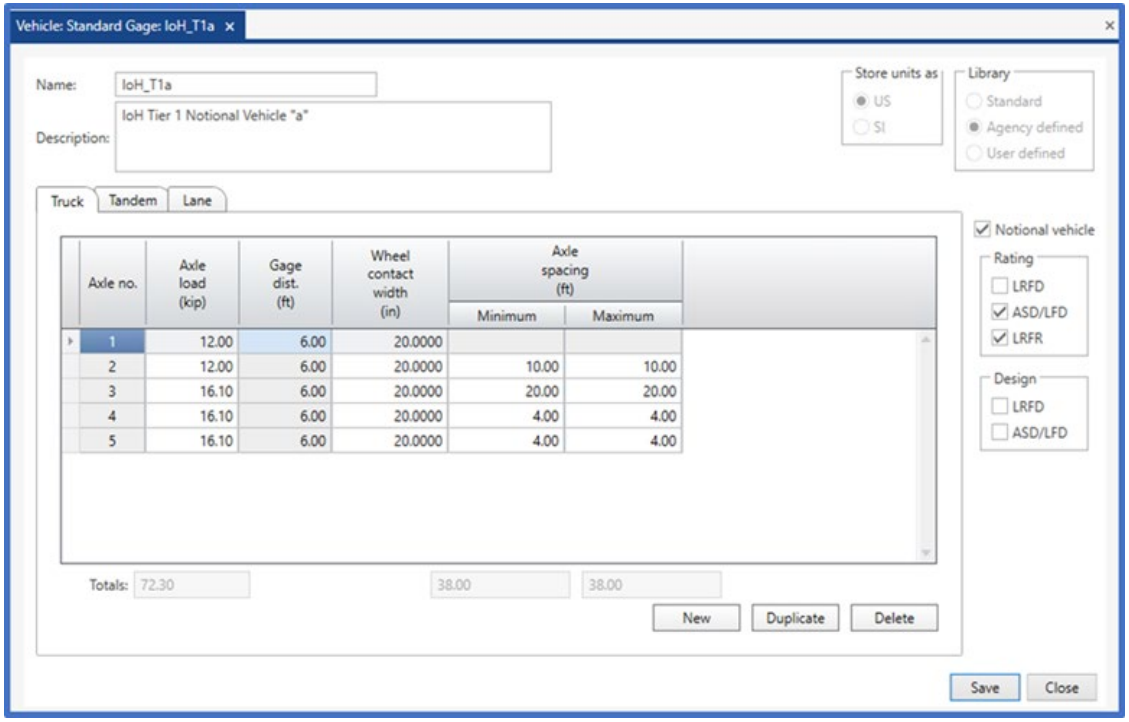
Load Ratings

AASHTOWare BrR Rating

1. Create the bridge to be analyzed in BrR.
2. Create the library of IoH Vehicles to be analyzed.
3. Adjust the impact factor to 0.61 which is an adjustment between normal highway traffic (33%) and IoH (20%).
4. Run the BrR analysis.

Load Ratings

a. Create Tier 1 IoH vehicle properties as per the NCHRP reports and as shown herein.

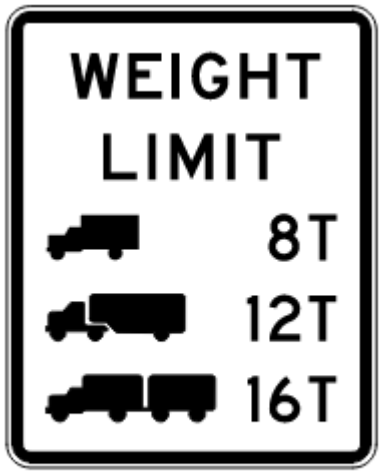


IoH_T1a completed input window

b. Create specific vehicles for Tier 2 and Tier 3 IoH vehicles as per specific vehicle axle spacing, wheel gage, and axle loads.

Postings

Postings



R12-5

Weight posting signs display the maximum safe weight for a vehicle. Since there are a number of different vehicle sizes and shapes on the roads, different types of vehicles called “Legal Loads” are individually analyzed. Each legal load type has a specified number of axles, axle spacing, and maximum weight per axle. This is shown on the R12-5 sign with three different vehicles.

Examples are dump truck, school bus, redi-mix truck, or garbage truck.

A standard semi is an example.

Example of this would be Fed Ex semi with two trailers.

Posting

R12-1 (old R12-1a)

R12-X11

R11-2M (old R11-2a)

R12-5M (old R12-5a)

MnDOT Bridge Load Rating and Evaluation Manual
Appendix G: MnDOT Load Posting Signs

Postings

Study of the Impacts of Implements of Husbandry on Bridges
Volume II: Rating and Posting Recommendations

Figure 47. Posting sign for a shorter bridge

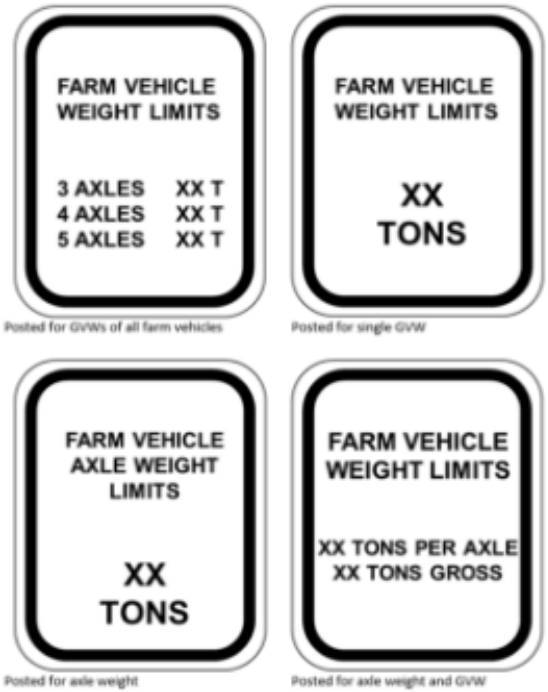


Figure 51. Farm vehicle posting signs

State Statute

State Statute

Minnesota State Statue 169.801 IMPLEMENT OF HUSBANDRY:

Subdivision 2. Weight restrictions. (a) An Implement of Husbandry that is not self-propelled and is equipped with pneumatic tires may not be operated on a public highway with a maximum wheel load that exceeds 500 pounds per inch of tire width.

(b) After December 31, 2009, a person operating or towing an Implement of Husbandry on a bridge must comply with the gross weight limitations provided in section 169.824.

Subd. 3. Hitches. A towed Implement of Husbandry must be equipped with (1) safety chains that meet the requirements of section 169.82, subdivision 3, paragraph (b); (2) a regulation fifth wheel and kingpin assembly approved by the commissioner of public safety; or (3) a hitch pin or other hitching device with a retainer that prevents accidental unhitching.

Subd. 4. Bridge posting. Despite subdivision 2, a person operating or towing an Implement of Husbandry must comply with a sign that limits the maximum weight allowed on a bridge.

Subd. 5. Height and width. A person operating or towing an Implement of Husbandry that is higher than 13 feet six inches or wider than allowed under section 169.80, subdivision 2, must ensure that the operation or transportation does not damage a highway structure, utility line or structure, or other fixture adjacent to or over a public highway.

Subd. 6. Speed. No person may operate or tow an Implement of Husbandry at a speed of more than 30 miles per hour.

State Statute

Subd. 7. Driving rules. (a) An Implement of Husbandry may not be operated or towed on an interstate highway.

(b) An Implement of Husbandry may be operated or towed to the left of the center of a roadway only if it is escorted at the front by a vehicle displaying hazard warning lights visible in normal sunlight and the operation does not extend into the left half of the roadway more than is necessary.

Subd. 8. Lights. An Implement of Husbandry must be equipped with lights that comply with section 169.55, subdivisions 2 and 3.

Subd. 9. Slow-moving vehicle emblem. An Implement of Husbandry must comply with section 169.522.

Subd. 10. Brakes. Notwithstanding section 169.67**:**

(a) A self-propelled Implement of Husbandry must be equipped with brakes adequate to control its movement and to stop and hold it and any vehicle it is towing.

(b) A towed Implement of Husbandry must be equipped with brakes adequate to control its movement and to stop and hold it, unless the Implement of Husbandry is in a combination of vehicles that meets the requirements of section 169.67, subdivision 5.

(c) If a towed Implement of Husbandry with a gross vehicle weight of more than 6,000 pounds, or more than 3,000 pounds if manufactured after January 1, 2011, is required under paragraph (b) to have brakes, it must also be equipped with brakes adequate to stop and hold it if it becomes detached from the towing vehicle.

Next Steps

Next Steps

- **State Statute**
  - State Statute would require amendment if axle loads are increased above 20kip to the 115% of Federal Bridge Formula (FBF).
- **AASHTO**
  - NCHRP 12-110 is a DRAFT of The Guide Manual for Bridge Evaluation for Implements of Husbandry and has not been adopted by AASHTO as of November 2022.
  - Prior to implementing specific program policy and/or procedures for evaluating in-service highway bridges regarding IoH, The Guide Manual should be adopted.
- **State Aid Bridge**
  - SHV contract based on this contracts notional load rating and mapping tool.
  - Potential mapping tool expansion in lieu of signing.

References

- Implements of Husbandry Bridge Rating Guide (AASHTOWare Bridge Rating)
- National Cooperative Highway Research (NCHRP 951): Load Rating Provisions for Implements of Husbandry (IoH)
- Iowa Research on IoH from Farm-to-Market Roads during Harvest Season
- NCHRP-12-110-3: The Guide Manual for Bridge Evaluation for Implements of Husbandry
- Transportation Pooled Fund Study - Study of the Impacts of Implements of Husbandry on Bridges

Questions?

Thank you for your participation!

Dave Conkel, dave.conkel@state.mn.us
Moises Dimaculangan, moises.dimaculangan@state.mn.us
Jim Bellefeuille, james.bellefeuille@tkda.com
Lindsey Lawrence, lindsey.lawrence@tkda.com