

Review and Revision of Overload Permit Classification ORBP Report No. RC-1589

Final Report

for



Baker

By Michael Baker Jr., Inc.
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**Technical Report
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Abstract

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16. Abstract <p>The Michigan Department of Transportation (MDOT) allows trucks that exceed their legal loads to cross bridges if they apply and are approved for a permit. More than 30,000 permits have been processed each year since 2002, providing a vital service to Michigan's economy. However, the permitting system must be robust enough to ensure that the safety of the motoring public is maintained by accounting for overload vehicles without unduly restricting commerce.</p> <p>Currently, structures are placed into Overload Class by checking all service limit states as identified by the 2005 MDOT Bridge Analysis Guide (BAG) with 2009 Interim Updates and the 2010 American Association of State Highway and Transportation Officials (AASHTO) Manual for Bridge Evaluation (MBE) with interims. Vehicles are placed into the Overload Class by comparing the maximum moments of the vehicle for span lengths between 15-ft to 160-ft to the moments produced by the 20 standard overload configurations provided by the BAG. Structures that do not pass an overload class would be marked as restricted and require a specific analysis, increasing the turn-around time for the client and the analysis cost incurred by MDOT.</p> <p>The current software used for the analysis of the structures is a simplified solution that was developed well over 20 years ago when more robust solutions were not feasible. With the capability of modern computing and the availability of bridge software solutions, this research project looks at solutions for updating the bridge analysis as well as the overall overload permit classification process.</p>			
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1 Executive Summary

The Michigan Department of Transportation (MDOT) allows trucks that exceed their legal loads to cross bridges if they apply and are approved for a permit. More than 30,000 permits have been processed each year since 2002, providing a vital service to Michigan's economy. However, the permitting system must be robust enough to ensure that the safety of the motoring public is maintained by accounting for overload vehicles without unduly restricting commerce.

Currently, structures are placed into Overload Class by checking all service limit states as identified by the 2005 MDOT Bridge Analysis Guide (BAG) with 2009 Interim Updates and the 2010 American Association of State Highway and Transportation Officials (AASHTO) Manual for Bridge Evaluation (MBE) with interims. Vehicles are placed into the Overload Class by comparing the maximum moments of the vehicle for span lengths between 15-ft to 160-ft to the moments produced by the 20 standard overload configurations provided by the BAG. Structures that do not pass an overload class would be marked as restricted and require a specific analysis, increasing the turn-around time for the client and the analysis cost incurred by MDOT.

The current software used for the analysis of the structures is a simplified solution that was developed well over 20 years ago when more robust solutions were not feasible. With the capability of modern computing and the availability of bridge software solutions, this research project looks at solutions for updating the bridge analysis as well as the overall overload permit classification process. In addition, a half-day training curriculum highlighting the software tools developed for this project was produced and presented to MDOT bridge engineers. This curriculum is provided with this research to be used as a tool for future training using the software.

2 Introduction

Statement of the Problem

MDOT allows trucks that exceed their legal loads to cross bridges if they apply and are approved for a permit. More than 30,000 permits have been processed each year since 2002, providing a vital service to Michigan's economy. However, the permitting system must be robust enough to ensure that the safety of the motoring public is maintained without unduly restricting commerce. In order to process these requests, the Bridge Management/ Load Rating unit of the Design Division (BMLR) classifies all bridges, and the Transports Permits Unit (TPU) of the Real Estate Development Services Division classifies the truck and then compares the two results. The computer program and methodology used to classify both bridges and trucks was last reviewed and modified in 1991. Since that time, changes have occurred in the business practices of each

Division. A new method of bridge design, analysis and rating has been adopted by the Federal Highway Administration (FHWA), MDOT and BMLR. Load and Resistance Factor Rating (LRFR) is required for load rating of new and reconstructed structures as of October 2010. This method replaced Load Factor Rating (LFR), which is anticipated to remain the method for existing structures. Additionally, a new program for processing permits has been adopted by the TPU.

Currently, structures are placed into Overload Class by checking strength and service limit states as identified by the 2005 MDOT BAG with 2009 Interim Updates and the 2010 AASHTO-MBE. Vehicles are placed into the Overload Class by comparing the maximum moments of the vehicle for span lengths between 15-ft to 160-ft to the moments produced by the 20 standard overload configurations provided by the BAG. Additionally, gage spacings greater than 8-ft are allowed to carry additional load as identified by the BAG. The formula given in the BAG was likely based on LFR distribution factors and does not account for LRFR. Structures that do not apply to this constraint are marked as Restricted by the BMLR and TPU and require a specific analysis, increasing the turn-around time for the client and the analysis cost incurred by the BMLR. Additionally, since the range of spans checked is always in the 15-ft to 160-ft range, vehicles may be restricted from routes based on span lengths that are not present on the route, which also leads to increased turn-around time for the client and additional analysis cost incurred by the BMLR.

Proposed Solution

To address these issues, the researchers have examined the current process, including reviewing the 20 overload standard vehicles, interviewing key MDOT personnel, making modifications to the existing software, reviewing the MDOT permitting procedures, exploring various software options, and reviewing the effects of the LRFR varying live load factors based on different weight vehicles. Based on these reviews, a new process has been recommended that maintains the reliability of the system and allows for efficient transportation of goods. This process is outlined in this report and includes the development of a new piece of software that will replace the software developed in 1991. This process takes into account the business practice which requires a quick turn-around of permit applications and also provides a methodology that could be implemented by local agencies as permits are not limited to state-owned routes. The software utilizes a hybrid of the AASHTOWare™ Virtis® software (which is licensed by MDOT) and a revision to the MDOT software developed in 1991 [NOTE: During the development of this research project, the name of the AASHTOWare™ Virtis® software was changed by AASHTO to AASHTOWare™ Bridge Rating. The research report has retained the original name 'Virtis' throughout this report]. The result is a program that operates as a standalone program, capable of being used by third-party developers for

inclusion in other programs (such as MDOT's MiTRIP software). The software includes a standalone interface and API (Application Program Interface) documentation for use by third-party developers.

Ultimately, the full success of the project relies on MDOT's continued development of their AASHTOWare Bridge database which will be used to accurately rate/analyze the state bridge inventory. The process is set up, however, in a manner that allows for the immediate implementation of the software prior to the full development of the bridge database.

3 Objective

The following were the research objectives of this project:

- Review current Overload Permitting procedure from the structure and vehicle perspective. Compare this procedure to current National Best Practices, MDOT and local agency business needs, and reliability of the system.
- Incorporating LRFR-determined bridge capacity ratings into the process as they become available.
- Create an interim report summarizing the current method, identifying deficiencies of the current procedure and proposing a method to be approved by MDOT.
- Create a software program to replace the current BridgeOV program that addresses all vehicle and structural variables outlined in the problem statement.
- Educate MDOT staff and Local Agency Bridge Owners.

The following sections provide a description of the methodology used to complete this research project. The project was divided into two phases: the Interim Phase review process which is described in Section 4 and the Final Phase which is discussed in Sections 5 and 6.

In general, the Interim Phase involved the review of Michigan's procedures, processes and existing software in order to provide recommendations that could be implemented in the Final Phase of the project and beyond.

4 Michigan Overload Permit Review Process

4.1 Methodology

The researchers reviewed the Michigan Overload Permit Review Process through document evaluation, data assessment, phone conferences and on-site visits in December 2010 and July 2011. The researchers performed these reviews in order to gain an understanding of Michigan's procedures for processing, reviewing and

approving overload vehicle permit requests. The purpose of the review was to develop recommendations to improve Michigan's automated system.

4.1.1 Documented Procedures

Published procedures for review of overload permit requests are documented in the Michigan Department of Transportation (MDOT) Bridge Analysis Guide (BAG), Chapter 8, Overload Procedures.

MDOT owns and maintains all bridges on and over Michigan (M), US and Interstate routes. However, for permitting purposes, bridges over MDOT-owned highways are the responsibility of the road owner even if the structure is owned by MDOT. Local bridge owners are not required to utilize the state's method of overload evaluation. Routine permit reviews are conducted by TPU who is responsible for issuing the permits.

MDOT has established a list of 20 vehicles to represent common overload permit vehicles typically requesting access to MDOT roadways. Each overload is broken down into three weight Classes A, B, and C. Class A considers each vehicle at the maximum weight, while Class B and C represent reduced axle weight configurations for each vehicle. Bridges are to be evaluated for their ability to carry each of the 20 permit vehicles. Those that can support all 20 loads at the maximum weight are identified as Class A bridges. Bridges which cannot support all 20 loads at the maximum weights are then evaluated at the lower set of axle weights. Those that pass all 20 loads at the Class B level are categorized as Class B bridges and those that pass all 20 loads at the Class C level are categorized as Class C bridges. If a bridge cannot pass all 20 loads at the Class C level, it is coded as Class D for restricted, and no overweight permits are issued to cross the structure. The configurations of these 20 vehicles have been in place for some time, and it is believed they were developed in the 1960's or 1970's.

For overload permit vehicles 1 through 5, 11 and 13 a second lower set of axle weights exists for Class B, and for permit vehicles 1 through 5 and 11, a lower set of axle weights exist for Class C. These are to be used in evaluating bridges designed for AASHTO H15-44 loading. Ratings for bridges designed for this lighter load may be controlled by the deck capacity for very large permit axle loads. The H15-44 design criteria was used in Michigan between 1965 and 1972. Bridges built between these dates that need the reduced axle loads to pass an overload class are to have an additional designation of an S Flag. Permit loads are only allowed to cross S Flag bridges if they are shown to have moments below the Class B or Class C moments the bridge is designated for and if the axle loads are less than 38 kips. It should be noted that the moments in the tables appear to have been developed using the full axle loads. There is not a second set of values for those trucks using the reduced axle weights.

The R Flag is used to designate bridges which have beam spacings greater than 10-ft as well as trusses and main girder type systems. If the R Flag is in place for a bridge, the axle weights for the truck are not eligible for a reduction if the actual axle width is greater than 8-ft. Allowable permit load tables used for comparison were computed using vehicles with an axle width of 8-ft. If the actual axle width is wider, the axle loads are reduced by a factor computed from the actual axle width for bridges without the R Flag. The equation to determine the factor is as follows: $\text{Axle weight} / ((\text{axle spacing} + 8.0) / 16)$. Each bridge is classified as either Class A, Class B, Class C or Restricted D and have the R or S flags designated by BMLR Division (see Figure 2 on page 11).

Haulers use a web based system known as MiTRIP. For the evaluation/comparison of their vehicle with the Class A, B and C loads, MiTRIP uses a version of the BridgeOV program developed by the Michigan Technological University and the Michigan Department of Transportation. When a permit is evaluated, a version of the BridgeOV program is run within MiTRIP for the load. Note, BridgeOV is run for all permit applications, even if the load is legal by weight. BridgeOV produces simple span moments based on the axle loads and spacings for the vehicle. They are produced for spans from 15-ft thru 160-ft at 5-ft increments using an impact factor based on the AASHTO Standard Specifications (LFD). These are compared against the Class A table of predetermined values for each of the above span lengths. For a Class A bridges to be crossed, all of the moments produced for the actual vehicle must be below the values in the table. If any of the checks fail, the load does not pass. The actual bridge span length(s) or configuration is not considered. Similarly for Class B and C bridges, the same checks are performed and compared against the Class B and Class C tables of allowable moment values.

4.1.2 Actual Procedures

Axle weights and spacings are input by the hauler as part of the MiTRIP application process on line. Reviewers from TPU staff receive output from MiTRIP which provides a comparison of the moment values of the actual load to the table values for Class A, B, and C bridges. The R and S flags are also considered by the system. MiTRIP also performs a check for maximum tire load per inch. The maximum load allowed is 700 lb/inch for hauled loads and 850 lb/inch for construction vehicles. The staff is limited in their reviews of BridgeOV output, review of the axle weights and the pass-fail responses from the system. No permits are auto issued by the system, all receive manual review first.

The data for MiTRIP is all developed by BMLR. In theory, all spans of all Michigan permitted bridges are analyzed for each of the 20 overload vehicles (Class A) and checked that they all receive a passing rating for both moment and shear.

If the permit load has an axle width greater than 8-ft, a reduction factor is calculated and applied against the axle loads. BridgeOV is also run with the reduced axle loads and those results are used in the comparison against the predetermined values. Appendix A provides an excerpt from the MiTRIP documentation on the use of BridgeOV.

Bridges which do not have all loads successfully pass as Class A are evaluated on their ability to pass all of the B and C loads respectively.

If the S flag has been assigned to a bridge, the load is checked (as a Class B or Class C bridge as designated) and the load cannot be passed if any of the axle loads are greater than 38 kips.

Loads which cannot be approved by TPU are typically returned to the hauler for re-distribution of the load or re-routing. If a load must reach a specific location via a route which cannot be passed by TPU, the permit application may be forwarded to BMLR for additional review. In this review, BMLR analyzes the bridge for the specific truck. This analysis may be performed by in-house staff and/or consultants, however, final approval is performed in-house. These individual reviews utilize all reasonable allowances to get the vehicles to pass and specific permit conditions (such as crawl speed, lane positioning and one truck at a time restrictions) may be required for approval of the permit. These reviews typically occur a few times per year and involve about twenty bridges per load review. During a particular manual review period, it was reported that Shear controlled for about 50% of the bridges checked (Phone Report – R.Curtis/B. Spangler – October 21, 2010).

The bridge capacity information is updated to the bridge database as the ratings are performed, however, this information is retrieved by the MiTRIP system quarterly. If the condition for a bridge changes, BMLR staff sends the revised bridge data to TPU by email for timely updating of MiTRIP data.

MDOT does not currently have the ability to quickly analyze a new vehicle over existing bridge models for the entire inventory. However, MDOT is currently in the third year of a six year plan to develop a sustainable database of bridge models for load rating purposes.

In Michigan, there are no requirements for local bridge owners to use any particular method to evaluate overweight vehicles. Also, BridgeOV is currently not available to local bridge owners to evaluate their own structures or the state owned structures carrying their highways over state owned facilities.

4.1.3 Project Constraints

One of the original tenants of this project is that no new data will be developed by MDOT and any new system must operate within the data constraints of the existing BridgeOV System.

Rising labor costs and advances in construction and fabrication have driven many manufacturers to fabricate very large components in specialized factory settings. This allows lower cost and tighter construction tolerances leading to more efficient machines. As a result of a shifting from on-site fabrication to more off site, plant fabrication is larger and heavier loads need to be transported. This trend is has resulted in specialized hauling companies who have modular hauling units that can be configured to transport extremely large loads in the ranges of half a million to over 2 million pounds.

A further spin-off of the superload hauling companies is the availability of the specialized equipment and the need to keep it employed. The use of these specialized vehicles is becoming more common to haul all types of oversize and overweight loads. These vehicles are typically a close arrangement of axles which can produce large shear forces on short span bridges in particular. More conventional trucks have greater spacing between and fewer axles in groups than some of the newer vehicles. BridgeOV as well as other states analysis methods focused on moments. The introduction of new vehicles places increased need for tools to check the effect of shear as well as moment.

Some other constraints:

- MDOT provided the researchers with the Bentley/MDOT documentation “SUPERLOAD: Permitting and Routing Implementation Michigan Department of Transportation System Specification”. Upon reviewing the documentation, it does not appear that any data is present for tire width, however, according to MDOT, the tire width is an input item in the permitting system.
- While Virtis is capable of analyzing a large percentage of bridges for Michigan, it is anticipated that there will always be certain bridge types that can’t be evaluated with the Virtis software or the BridgeOV software. These bridges may need to be reviewed on a case by case basis based on the condition, performance, and approximate, conservative values assigned as BridgeOV classes.

4.1.3.1 Existing Data

The existing data on MDOT bridges is limited to the NBI data which includes the following fields relevant to permitting:

- Structure Number (NBI Item 8)
- Number of spans in main unit (NBI Item 45)
- Length of maximum span (NBI Item 48)

- Structure length (NBI Item 49)
- Overload Class (NBI Item 193)

Note: NBI item 193 is only used for Michigan and not delivered with the final NBI database to the FHWA.

The availability of some or all of these fields will be necessary for various options mentioned in subsequent sections.

Existing data consists of each Michigan permitted bridge being assigned an A, B, C or D class. Additionally a subset of Class B and C bridges also may have an S flag associated with them. Any bridge may be assigned an R flag, but it would not be logical to also assign it to one with an S flag.

Also available is the existing BridgeOV program which has built into it a table of moments for span lengths from 10' – 200' for Class A, B, and C structures. Note, data above 160-ft is not currently used. Eighty-nine bridges in the MDOT NBI database have main spans of 160-ft or greater.

4.1.3.2 Data Acquisition

During the Interim Phase, the researchers received two files containing the vehicle data of actual permit applications involving 8000+ permits. The large amount of data was sorted electronically by writing a simple program to sift through the permit vehicle data provided by MDOT and using it in combination with Excel. The data was sorted by axles and load and then manually reviewed to select a subset of vehicles which would generate the greatest moments and reactions. Thirty-one vehicles were selected initially and eventually reduced to 25 vehicles. These 25 vehicles are proposed to be used in Section 4.3.3 to determine the applicability of the existing permit vehicles to predict actual loads. A list of the 25 selected vehicles along with a comparison for Class A, B, and C moments provided in BridgeOV is shown in Appendix D.

The software used for the sorting of the permit vehicle data during this Interim Phase was enhanced in the Final Phase to include more sorting capabilities. It was used in the Final Phase of this project to more thoroughly analyze large sets of permit vehicle data provided by MDOT (see section 5.1.1):

4.1.3.3 MDOT Bridge Demographics

MDOT NBI Demographics

From the NBI data MDOT has submitted to FHWA, some insight can be gained into the MDOT bridges from their ages, the main span material and span continuity.

Age of Bridges vs. Material Used in Main Span

- The chart below shows the material of the main span plotted against the decade in which the bridge was built.
- The large number of steel bridges built between 1950 and 1979 are all now over 40 years of age and entering a stage where deterioration is more probable with subsequent loss of capacity.

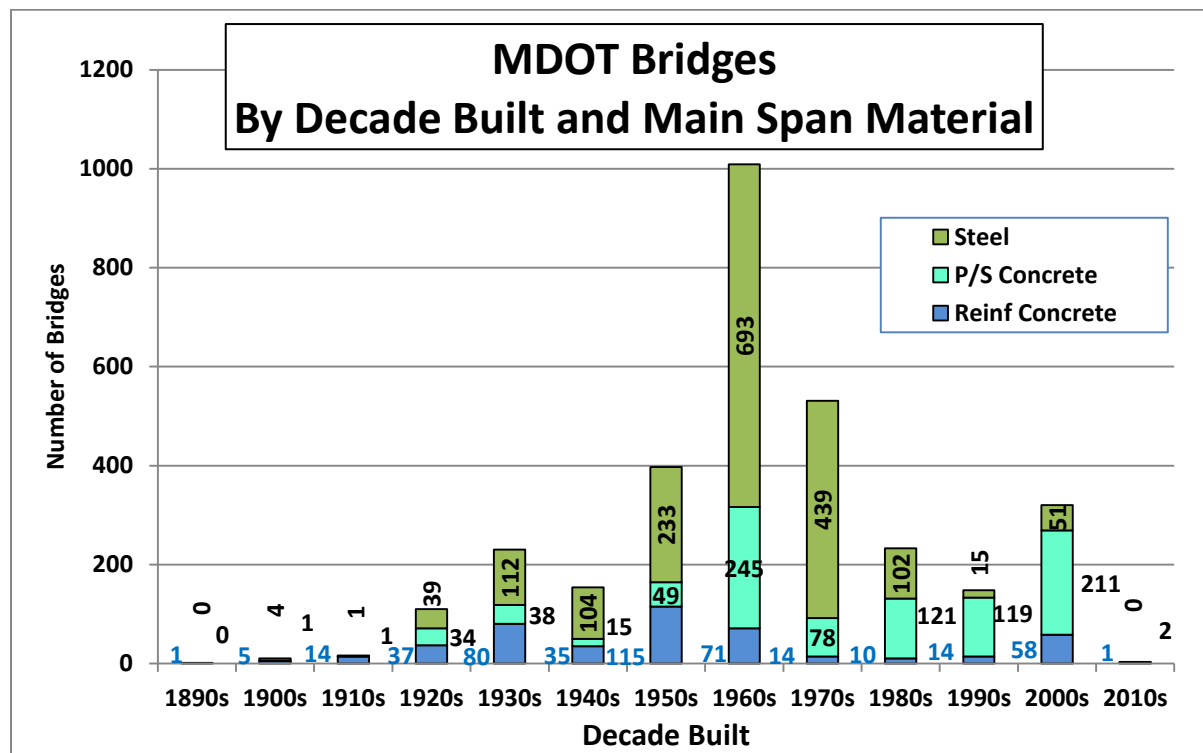


Figure 1. Michigan bridge distribution by decade and bridge type

Relative Simplicity for Analysis

As shown in Table 1, the MDOT bridges lend themselves to analysis by less complex engineering programs:

- Over 90% of the bridges have simple-span main spans of steel, reinforced concrete or prestressed concrete.
- Only 30 steel bridges consisting of 49 main spans (including trusses, arches, box girders, suspension) are not I girders.

- The NBI data does not identify girders that are horizontally-curved requiring higher-order analysis. It is estimated that less than 10% of remaining main steel spans are curved.

Table 1. Michigan NBI distribution

	Number of Bridges			Number of Spans		
	Simple Span	Cont. Span	Total	Simple Span	Cont. Span	Total
Reinforced Concrete	356	99	455	462	337	799
Steel	1,626	167	1,793	5,025	976	6,001
Prestressed Concrete	908	6	914	2,242	76	2,318
Other	3		3	5		5
TOTALS	2,893	272	3,165	7,734	1,389	9,123

Overall Bridge Condition

The overall condition of the bridges is good with only 8% being Structurally Deficient at the time of the query, which would limit the number of re-ratings needed solely due to deterioration.

Current Bridge Capacity

The MiTRIP class distribution (see Figure 2) was created from the bridge list for MiTRIP and indicates a large proportion (2816 of 3185 total bridges ~ 89%) of the bridges as being Class A, meaning that they can safely carry all current Michigan Overload trucks.

- The number of S flag bridges (designed for H15 loads) may be under-reported. A review of the NBI data shows that 386 bridges were built with a design load less than AASHTO HS20-44.
- 823 bridges (26% of total) were designed using the AASHTO HS 25 loading.
- The apparent discrepancy in values may at least partially be explained as some bridges had narrow beam spacings such that the H-15 loading would not control and other bridges may have had deck replacements or other major rehabilitations which would account for the differences. It is recommended that MDOT further investigate the individual bridges.

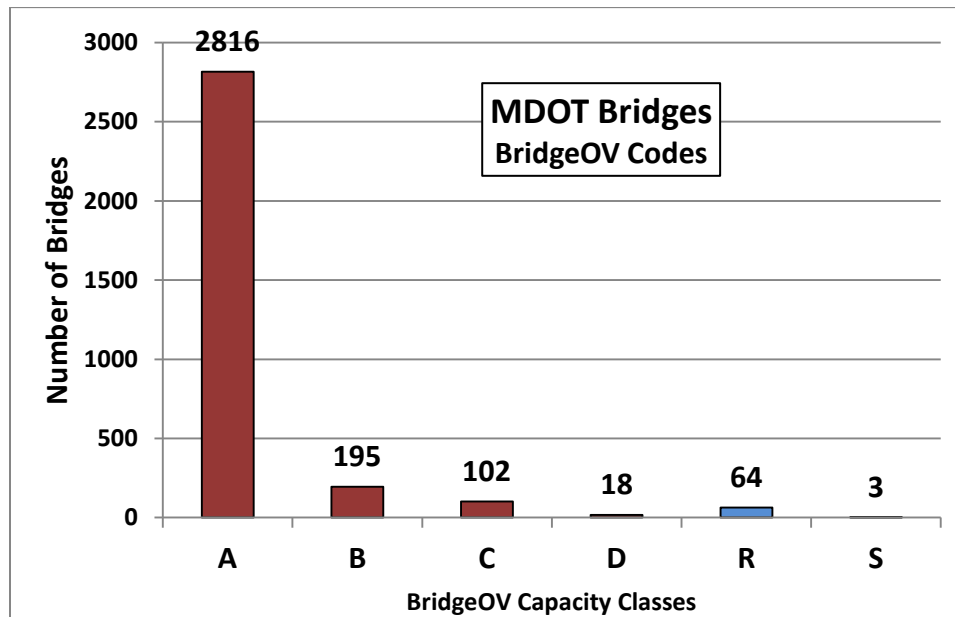


Figure 2. MiTRIP class distribution

Current Bridges with Virtis Ratings Compared to Permit Loads –

The chart provided in Figure 3 shows the number of bridges by main span length along with 3 vehicles selected from the MDOT permit list and showing the moment ratio of the vehicle to an HS20 loading.

- The ratio of maximum moment for three typical permit vehicles versus HS 20 loading was plotted for each span range to demonstrate the load demand of modern permit vehicles.
 - For a considerable span range (20-ft to 120-ft) that makes up 90% of MDOT's bridges, the maximum moment exceeds 200% of HS20 loading.
 - The three vehicles weighing 150 k, 208 k and 289 k each were selected from actual MDOT permits.

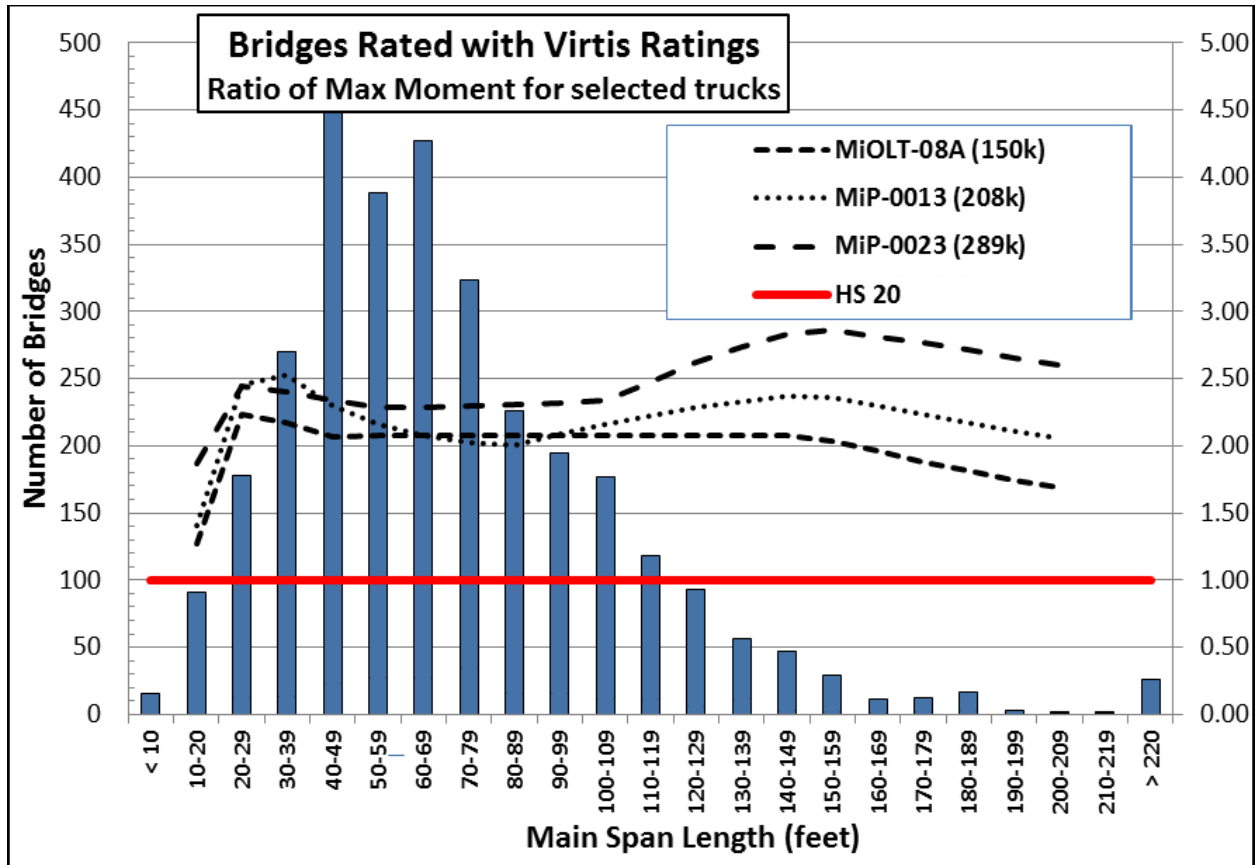


Figure 3. Bridges rated with Virtis ratings

MDOT Virtis DB Demographics

During the Interim Phase, MDOT provided a Virtis bridge database totaling 225 Bridges to the researchers . All bridges ran through and produced LFR ratings with the exception of Bridge IDs 527, 617, 717, and 776.

Some or all portions of these bridges did not run through completely. The graphs shown in Appendix B represent a breakdown of the bridges by year and structure type based on data extracted from the Virtis database.

Note that the total number of superstructures (545) is larger than the total number of bridges submitted (225). Virtis permits the entering of multiple superstructure definitions per bridge; the breakdown shown in the graphs and tables is by structure.

Comparing the Virtis DB breakdown to the bridge breakdown shown in the previous section reveals the following:

- The ‘Year built’ (see Appendix B) for the Virtis DB compares favorably to the ‘Year Built’ distribution.
- The distribution comparison for different structures is shown in Table 2 below. While there are some variations in the quantity of each bridge type, we believe they are close enough to be used as a representative distribution of the Michigan inventory.

Table 2. NBI bridge distribution vs. Michigan Virtis DB

Structure Type	NBI distribution (See Previous Section)	Virtis Database Distribution (See Appendix B)
Prestressed Concrete	29%	40%
Steel	57%	52%
Reinforced Concrete	14%	8%

4.2 Discussion of Results/ Conclusions

While the most likely long-term option for bridge rating for Michigan is the use of Virtis, short-term options will be needed to fill the gap until a larger portion of the MDOT bridge inventory is input into Virtis. In addition, the short term options also fulfill the need to provide a ‘non-Virtis’ solution for the MDOT locals. The advantages and disadvantages of the options listed below are provided in this section:

- Option 1 – Modify the existing BridgeOV software
- Option 2 – Using a refined analysis technique
- Option 3 – Using Virtis
- Option 4 – Combining Options 1 and 3

4.2.1 Option 1 – Modify BridgeOV

This method is probably the simplest but does not provide much in the way of increased analysis capabilities. The current capabilities of BridgeOV are described in Appendix C of this document. For this option, additional features would be added, including the evaluation of shear. This would require the development of a table of shear values per span length similar to what exists for moment. It would also require checking existing bridges for shear or assuming that the existing classes for moment classes of A, B and C apply for shear as well. This process could be modified by running the specific maximum span length (passed from the routing package) for the vehicle in question and the vehicles from each A, B or C class. Using the maximum span length available in the NBI data for BridgeOV was investigated in the final phase of this project and is presented in section 5.1.6.

Advantages	Disadvantages
<ul style="list-style-type: none"> • Simpler to implement • Does not require direct use of Virtis • Can be modified to include shear • Provides a program that can be used by locals 	<ul style="list-style-type: none"> • With the criteria of no new data, this would assume that the existing A, B and C classifications are also adequate for shear • Only uses simple span distribution • Lowest level of analysis

Modifications for BridgeOV for this option would include updates for a more manageable future maintenance of the programming, functional updates, and updates for further investigation of the existing Michigan overload vehicles. These include the following, which are further described in the next sections:

- Update BridgeOV to C#.NET
- Expand the span length to represent the Michigan bridge demographics
- Check or validate the Class A, B and C moments currently built into BridgeOV, and include new permit vehicles to the envelope if necessary.
- Evaluate both existing and new permit vehicles for shear to determine effects and to justify the inclusion of performing the additional checks
- Add shear capabilities for use in conjunction with the moment check and possible verification of effect of shear on existing structures (shear values imposed cannot exceed the loadings of the existing permit vehicles, and the new proposed vehicles may need to be proportioned down from the actual loads to meet existing evaluation capacities)
- Include a graphing option
- Possible inclusion of call to Virtis (see Recommendations section)

4.2.1.1 Update BridgeOV to C#.NET

The most current version of BridgeOV is written in the C programming language. For this option, we propose using C#.NET for Developer Studio 2010. This takes advantage of the Microsoft programming environment to include additional features for BridgeOV. The actual calculation routine for the current BridgeOV module is relatively simple, so a prototype of the C# program is currently working.

Creating the new program also creates a user-friendly environment that can be used by locals (i.e., outside of TPU as a standalone version).

4.2.1.2 Expand Span Length to Represent the Michigan Bridge Demographics

The current version of BridgeOV only examines spans up to 160' in length. This can be modified to 200-ft (the A,B,C class moment file includes span lengths up to 200-ft). It

can be expanded to lengths beyond 200-ft by using Virtis to calculate the A,B,C class moments for the longer span lengths with the existing overload vehicle loads.

In addition, if the 'Maximum Span Length' available from the Michigan NBI data is passed to BridgeOV, the evaluation of the span lengths could be performed on bridge lengths from 15-ft up to and including the maximum span length. Another option would be to continue to use the current process of checking all span lengths for bridges with spans less than or equal to 160-ft and also to check all span lengths up to the maximum for all span lengths greater than 160-ft.

4.2.1.3 Validate Class A,B, and C Moments in BridgeOV

The moment tables for Class A, B, and C loads provided in BridgeOV were developed over 20 years ago and should be reviewed for accuracy. They also should be reviewed in light of the LRFD Specifications, particularly with respect to live load factors. If new permit vehicles are to be added to the Class A,B,C envelope, they should be used to modify the tables.

4.2.1.4 Add Shear Capabilities

The original version of BridgeOV did not have an option to check shear. An option was proposed and added in the final phase to calculate the shear for the vehicle input. In order to compare, the Class A, B, and C shear values were computed and placed in a table similar to the moments. Before adding these capabilities, the researchers investigated the benefits of adding shear. The results of this investigation are described in sections 6.1.2 and 6.1.3.

4.2.1.5 Provide Graphing Features

Moving the software to a C#.NET environment allows for additional features to be added to BridgeOV, such as graphing and enhanced reporting, making it more useful as a standalone program for local users of the software. A modified BridgeOV prototype is shown in Figure 4 below. The final modifications to BridgeOV are described in detail in section 6 of this report. This option would be particularly useful for the evaluation of the overload vehicles.

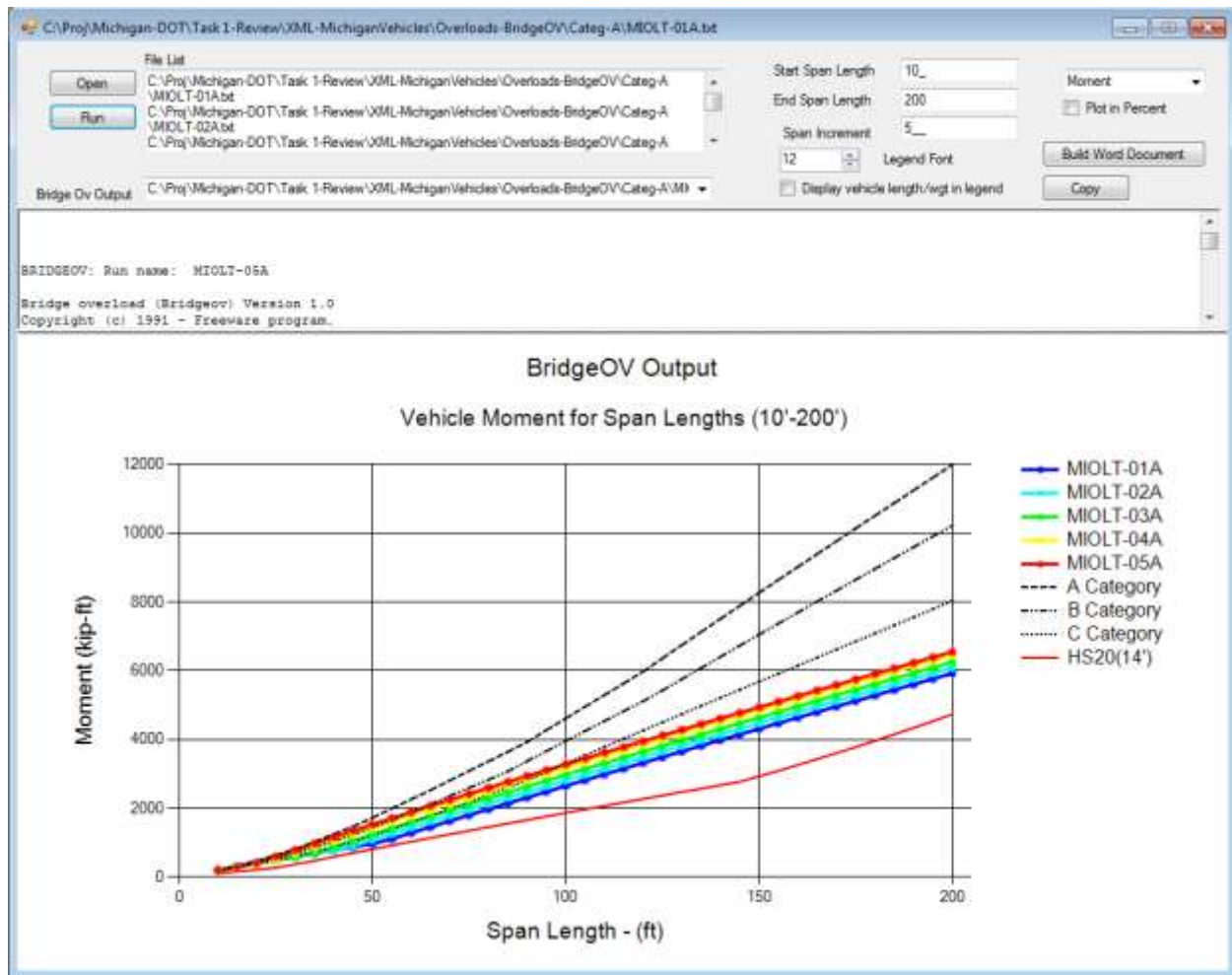


Figure 4. BridgeOV prototype

4.2.2 Option 2 – Using a Refined Analysis Technique

This option calls for replacing the existing BridgeOV software with an analysis module that would provide a more refined and accurate approach for analyzing the bridge. A FORTRAN module is available that can analyze continuous structures given the span length configuration. It will analyze both simple and continuous spans and has the capability to handle hinges and floor beams (if information is available to define these structural items).

The key for the level of refinement provided by this option is the amount of data available to properly define the structure; the more data available (e.g., span lengths, span configuration for multiple spans, cross section information (less likely to be available), hinges (less likely to be available), etc.), the more refined the analysis. As

more and more data is made available, the closer this moves to Option 3 (Virtis Analysis).

For this method, in addition to the permit vehicle in question being run, all of the overload vehicles for the class would need to be run as well. An envelope of shear and moments for the overload vehicles for the needed class (A, B or C) would be built and compared with the permit vehicle moments and shears.

Advantages	Disadvantages
<ul style="list-style-type: none"> • More refined analysis • Does not require direct use of Virtis • Could potentially run as a standalone 	<ul style="list-style-type: none"> • More Refinement requires more data • Required data may not currently be available to pass down from the routing system • Assumes prismatic sections as section property information would likely not be available • This work would ultimately be replaced by Virtis

4.2.3 Option 3 – Using Virtis

Option 3 involves using AASHTO Virtis directly. Using this process would permit the bridge (or bridge system) to be defined directly and would allow any condition changes in the structure to be included. This method requires that the bridges in question be available in a Virtis database. A simple diagram of how this process of running Virtis in this 'Batch Mode' would work is shown in Figure 5. This method has been developed and is in the process of being tested for Oklahoma DOT. The method relies on the true bridge description and is still viable when new and improved versions of the software become available.

Virtis may also be used to consider:

- Potential uplift at girder ends on continuous bridges
- Increased shear in obtuse corners of sharply skewed bridges (may be critical for steel)
- Non-standard truck gage
- Fascia beams

Advantages

- Actual analysis of the defined structure
- Virtis is continually being upgraded to the latest specification changes

Disadvantages

- Virtis structures are not currently all input
- Structures that Virtis cannot handle (e.g. suspension bridges) cannot be analyzed
- Longer run times
- Would not benefit local agencies that do not use Virtis

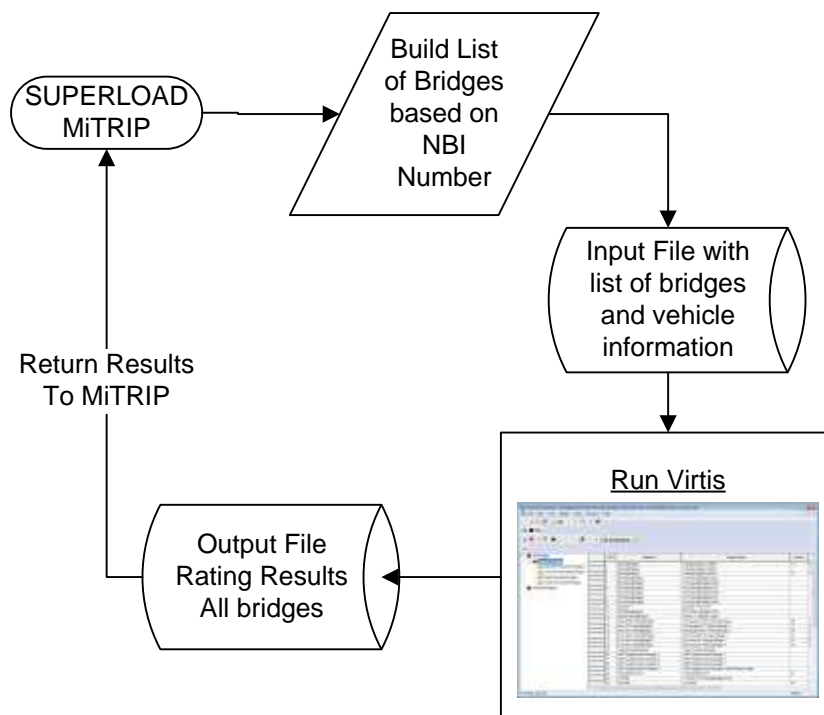


Figure 5. Running Virtis in 'Batch Mode'

4.2.4 Option 4 – Combination of Option 1 and Option 3

Option 4 provides a hybrid of Options 1 and 3. An example of how this would work is demonstrated in Figure 6. The idea is that BridgeOV would be utilized much as it is today but would require using the NBI number. Within BridgeOV, a call would be made to a copy of the existing Virtis database with a dedicated version of the input datasets to see if the bridge is in fact present in the current Virtis database. If so, Virtis would be run and the rating factor returned; if not, the modified version of BridgeOV would be run (see Figure 6).

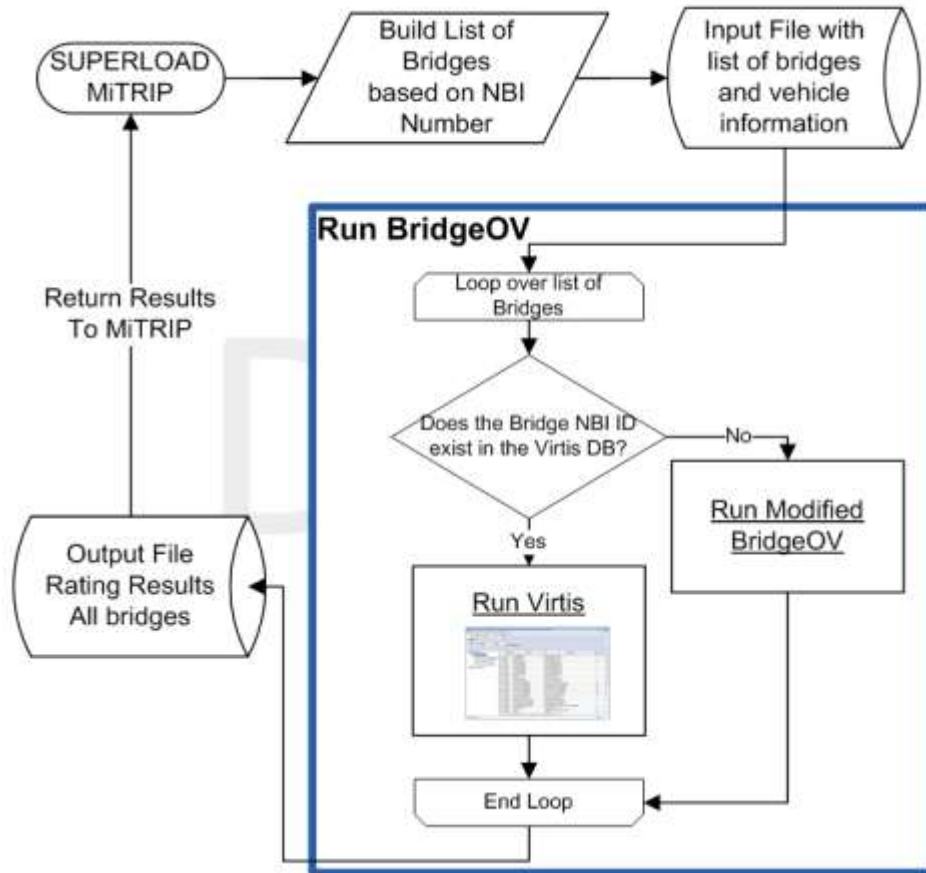


Figure 6. Running BridgeOV with Virtis option in 'Batch Mode'

The ability to run Virtis in this mode would be built on the enhancements to Virtis that Oklahoma DOT has funded which provide for running Virtis and returning rating factors in a 'batch mode'. These enhancements, although initiated by Oklahoma DOT, are available to all licensees of Virtis.

This method will allow MDOT to begin the transition of using Virtis at an earlier time and will allow for inclusion of newly input Virtis bridges as they become available. It will also include the enhancements to BridgeOV as discussed in Option 1.

This option also allows for running this as a standalone program (i.e., without the use of MiTRIP). Figure 7 shows a similar flowchart but with the initiation of the program coming from an interface other than MiTRIP. This will be a simple interface that will work with a group of bridges and a single permit vehicle (see Figure 7). To provide security, for use by locals, an option can be provided to bypass Virtis.

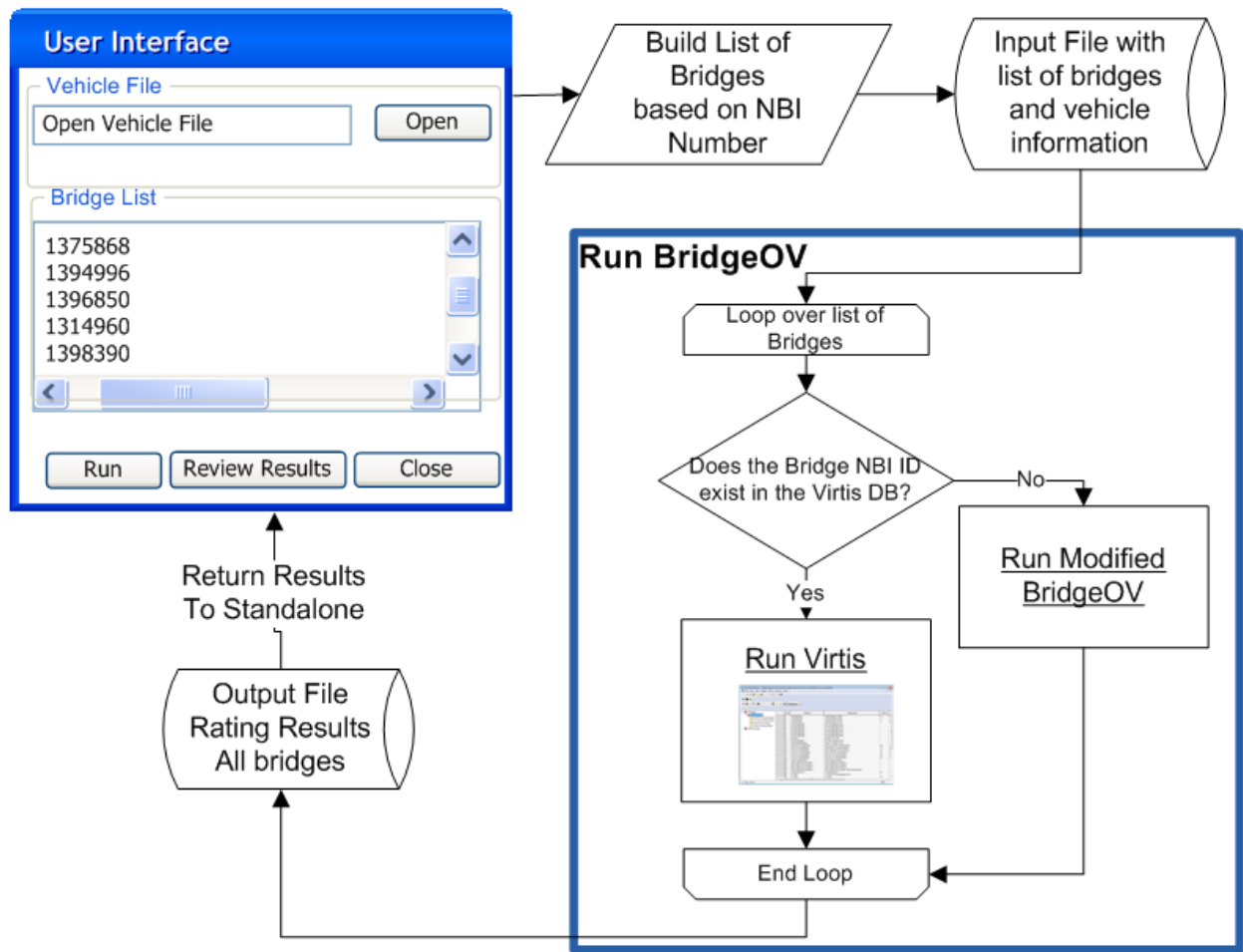


Figure 7. Running BridgeOV with Virtis using 'Standalone'

The database for Virtis would need to be dedicated for permitting and would need to be updated by the bridge group for condition changes. The output provided by the BridgeOV-Virtis Interface will be of pass/fail variety.

Advantages	Disadvantages
<ul style="list-style-type: none"> • BridgeOV Can be modified to include Shear • Can be used as a standalone for local bridges. • Combines benefits of Option 1 and Option 3 • Can be used now with a more robust solution in the future as additional Virtis bridges become available • Makes additional and cost-effective use of MDOT's commitment to Virtis ratings • Can re-evaluate for changed conditions in bridges • Good transition option 	<ul style="list-style-type: none"> • Small number of Virtis bridge currently available • Until more bridges have Virtis ratings, the disadvantages of Option 1 remain • The time needed to substantially increase the number of Virtis ratings

4.3 Recommendations

The challenge for implementation will be to provide a short-term solution that can transition to the ideal long-term solution. The following was recommended at the Interim Phase of this project:

- For a programmatic solution, use Option 4 which implements a short-term solution with ultimate long-term goals for integrating the Virtis software into the rating process.
- Review the existing Legal Loads and Permit Loads to determine which, if any, can be eliminated.
- Review our sampling of actual loads and determine if any loads need to be added to the existing group of Michigan permit loads to reflect modern hauling vehicles.

4.3.1 Use Option 4 – Combination of Option 1 and Option 3

While Option 2 improves the accuracy of review over the BridgeOV review with its incorporation of multiple span lengths for each bridge, it is not a good strategic solution because of its immediate need for additional data without the accuracy of Virtis. Moreover, the Option 2 data doesn't meet the data needs for the long-term adoption of Virtis for MDOT bridge ratings.

The researchers believe the best short-term solution is Option 4 (or a combination of Option 1 (updating BridgeOV) and Option 3 (beginning the integration of Virtis). Of course, initially the more accurate Virtis analysis would be available only for bridges with a Virtis dataset, but additional bridges could be added as they are rated for NBIS - short-term benefits with an integrated long-term Virtis solution.

4.3.2 Reviewing the Existing Loads Using Virtis and BridgeOV

The researchers also recommend the review of the existing permit loads and legal loads (for comparison with the overloads) to determine if all the individual loads are necessary to represent the potential permit vehicles and if their moment (and possibly shear) envelopes represent different loading conditions or if any can be eliminated. With revisions to BridgeOV and the Virtis database provided, all of the vehicles can be plotted together or separately.

To perform this task, the existing Michigan legal load and overload vehicles can be plotted together using BridgeOV results. The researchers can also plot the results of these vehicles using results of 2 and 3 span continuous bridges to see if any of the vehicles may be eliminated.

4.3.3 Comparison of Sampling of Permit Vehicles

During the Interim Phase, the researchers reviewed a list of permits provided by MDOT (see section 4.1.3.2). This set of actual permit applications included axle loads and axle spacings (gage distances were not included). The researchers reviewed this selection of permit vehicles using software developed during the interim phase that allowed for the conversion of the data provide by TPU into a format that could be sorted in a spreadsheet. This included the conversion of axle spacings from ft-in format into decimal format and to eliminate duplicate vehicles (i.e. vehicles with identical number of axles, identical axle spacings and axle loads).

After the conversion of the vehicle data using the software and sorted in a spreadsheet, it appeared that several of the vehicles were believed to induce greater moments and almost certainly greater shears than the existing group of permit vehicles. This was confirmed by reviewing a set of 25 of the permit vehicles using a version of BridgeOV that was revised for the Interim Phase. The results of this preliminary review of the 25 Michigan permit vehicles is provided in Appendix D.

Based on the review of the 25 permit vehicles described in Appendix D, the list of vehicles was further reduced and analyzed using the 225 Virtis bridge database provided by MDOT and the results compared with results for BridgeOV. The results of this analysis and comparison are provided in Appendix E.

Based on this preliminary permit vehicle review, the researchers recommended a further review of the permit vehicles. To facilitate this review, MDOT agreed to provide the following for the final phase of the project:

- Virtis input files for a set of 30 continuous span structures
- A full year of permit vehicle data (16,000+ vehicles).
- The Virtis sample will include additional bridges with the R flag

From the data provided, the following was recommended for the Final Phase of the project:

- Review the new list of permit vehicles. The permit vehicle software started in the Interim Phase was modified to facilitate this analysis and is provided in the final software deliverable.
- Review the effect of continuity using the database of 30 continuous structures provided by MDOT.
- Determine if some vehicles from the Class A overload category may be eliminated because they are enveloped by other overload vehicles.
- Review the effect of the R flag.

5 Reviewing the Permit Vehicle List and Michigan Overload Vehicles

Michigan DOT provided the researchers a spreadsheet list of Permit vehicles (axle_weight_spacing7_23_11 to_7_24_12.xls) that was analyzed using software developed for this project. The overall statistics for the vehicle breakdown are as shown in Table 3 below.

Table 3. Breakdown of permit vehicle list provided by TPU

Period 4/23/11- 4/24/12	
Total Number of Vehicles	16,124
Number of Unique Vehicles	10,006
Number of Duplicate Vehicles	6,118

For the purpose of comparing, duplicate vehicles are ones that have the exact number of axles, the exact load/axle AND the exact axle spacing. Table 4 below represents the breakdown of the unique vehicles sent by number of axles. This list of vehicles was used in comparison of the overload vehicle curves developed for the revised BridgeOV software.

Table 4. Break down of MDOT permit vehicle set from

#axles	Number of Vehicles
1	0
2	21
3	44
4	398
5	4213
6	2334
7	1382
8	889
9	246
10	180
11	157
12	31
13	90
14	2
15	1
16	0
17	0
18	7
19	9
20	2

5.1 Methodology

Since reviewing the analytical results of all 16,000+ vehicles provided by MDOT was prohibitive, a systematic approach was developed to sort and organize the data to selectively choose vehicles to be analyzed. This included the following:

- Developing software for reading in the permit vehicles and sorting them in different ways.
- Using the revised BridgeOV software to perform the analysis of the software (see Section 6 of this document for a description of the changes to the BridgeOV software).
- A review of vehicles that were most often permitted (i.e. vehicles with identical axle spacings and axle loads).
- A review of vehicles that appear to have anomalous data, such as unusually small axle spacings or large loads.
- A review of vehicles with the largest axle concentrations (2 axle, 3 axle, 4 axle and 5 axle).
- A review of vehicles with the largest gross weight.
- A review of a 5 axle vehicle with 4-ft axle spacings and 24 kip loads. This was requested directly by MDOT.
- A review of the Michigan Overload vehicle list for possible elimination of some vehicles.
- A review of 30 continuous structures provided by MDOT to determine if BridgeOV is conservative
- The effects of using the maximum span length information provided in the NBI data record for each bridge.
- A review of the effects of the proposed Michigan LRFR load factors that vary with the gross weight of the vehicle.
- Note that in all results, the gage distance was not provided in the spreadsheet. Only axle loads and axle spacings are provided.

The process of developing the above mentioned criteria and the results of the analysis are described in detail in the following subsections.

5.1.1 Software for Reviewing Permit Data

In the Interim Phase of this project, the Permit Vehicle Analyzer (PVA) software for analyzing large amounts of permit data was developed. The software works with the spreadsheets (modified) provided by MDOT and has been used to analyze the permit data. The software will be delivered to MDOT as a deliverable for use by the MDOT and local agencies after this research is completed.

- Duplicate vehicles are detected and marked.
- The vehicles are stored into memory and can then be manipulated or analyzed.
- The vehicles that are selected as the results of an analysis may be saved as BridgeOV input files or Virtis XML vehicle files or moved to an excel spreadsheet.

A sample of the interface is shown in Figure 10. A more detailed description of the functionality of the PVA software and the process for converting the spreadsheet into the necessary CSV file are provided in Section 10.4.1 of this documentation.

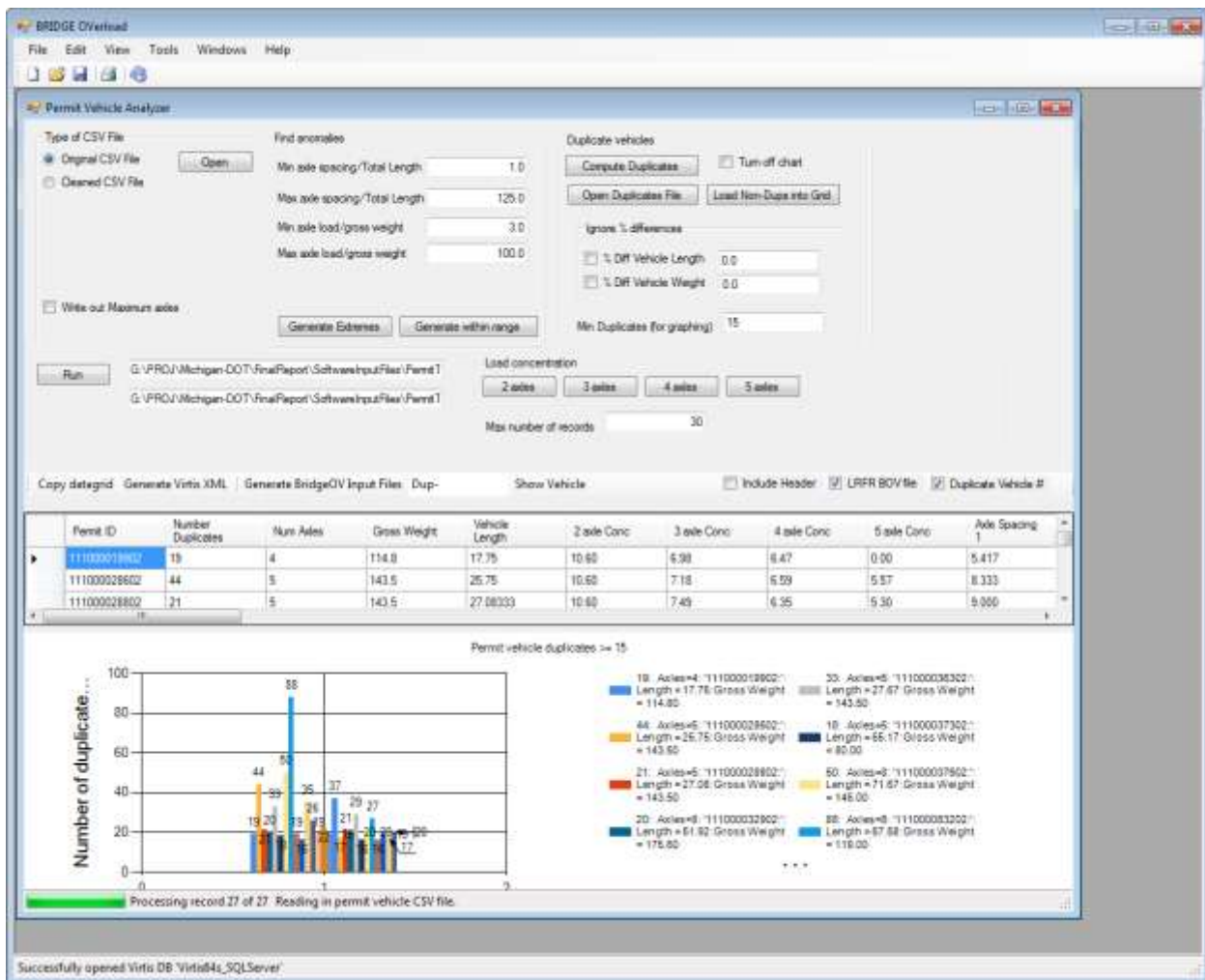


Figure 10. MDOT Permit Vehicle Analyzer (PVA) software

5.1.2 Duplicate Vehicles

Using the PVA software, the top vehicle frequencies were identified (i.e. the maximum occurrences of duplicate vehicles). The vehicles with duplicates greater than or equal to 15 are shown in Figure 11. These vehicles were reviewed to get a sense of the effect on the most duplicated vehicles in the system.

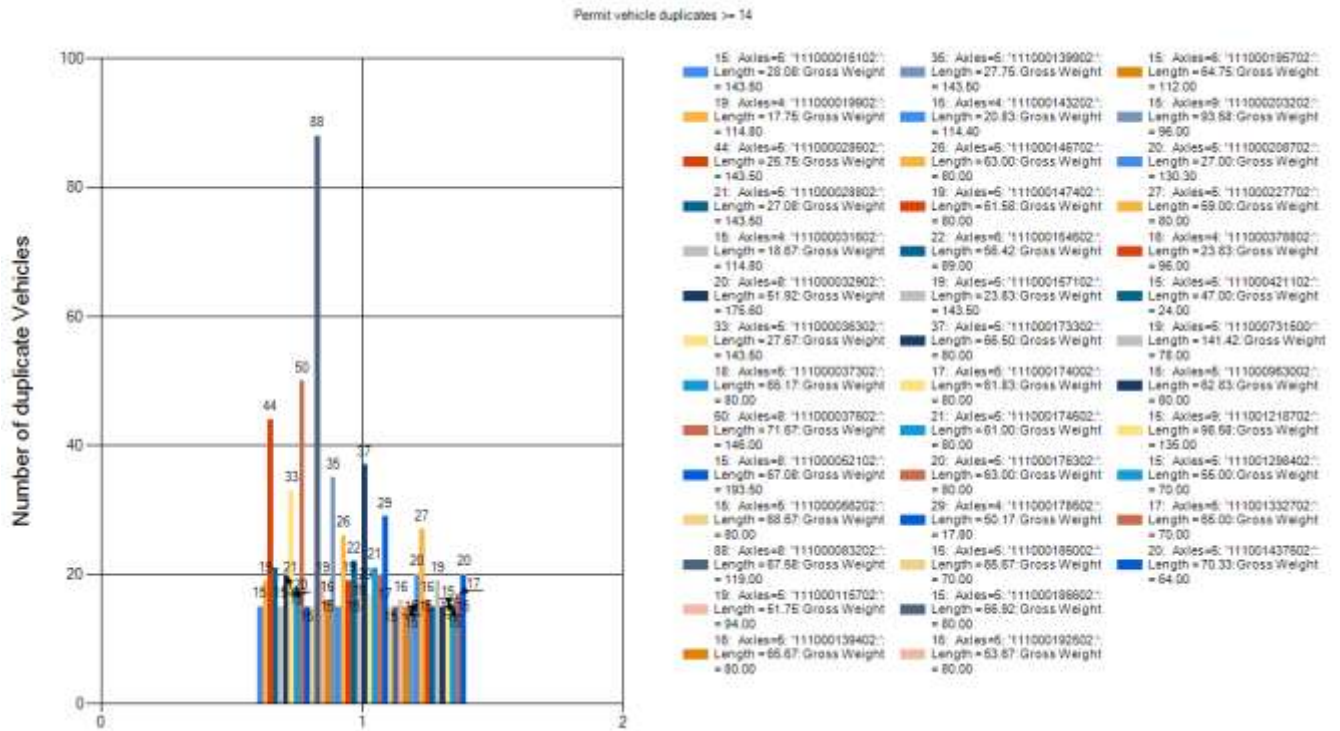


Figure 11. Frequency of duplicate vehicles

Running these vehicles through BridgeOV produces the graphs shown in Figure 12 through Figure 17.

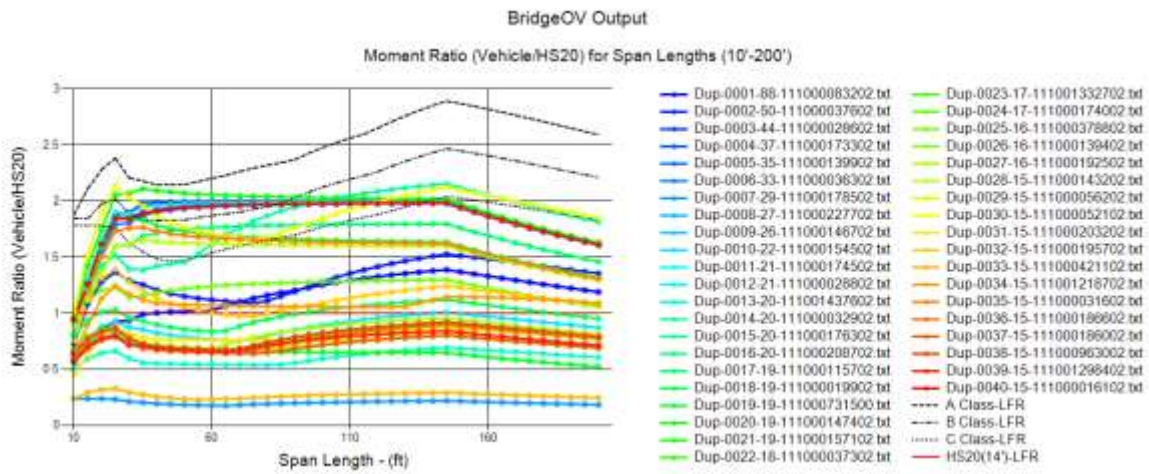


Figure 12. BridgeOV Moment ratio of top 40 duplicate vehicles

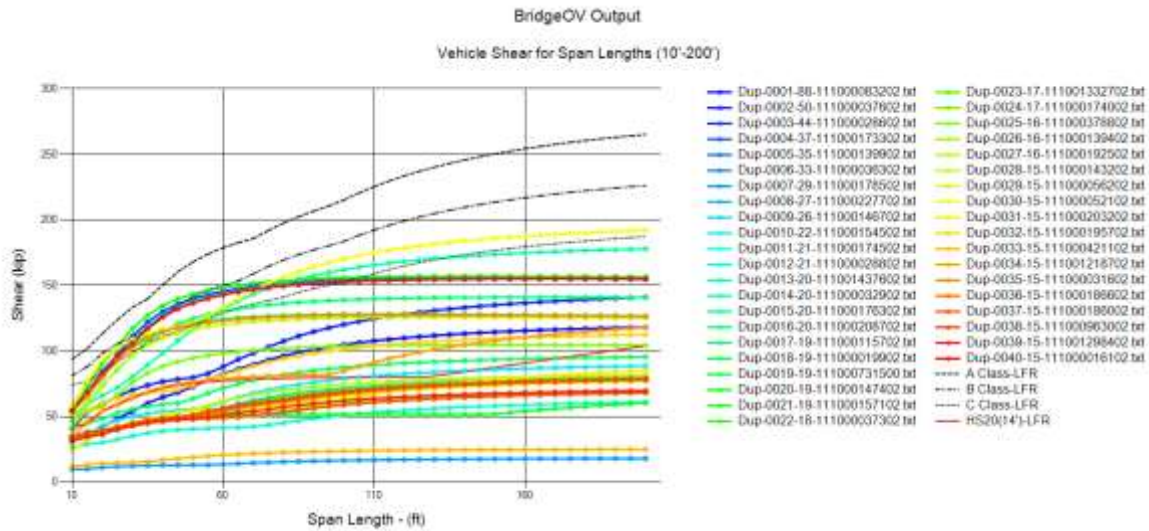


Figure 13. BridgeOV Shear (simple span) for top 40 duplicate vehicles

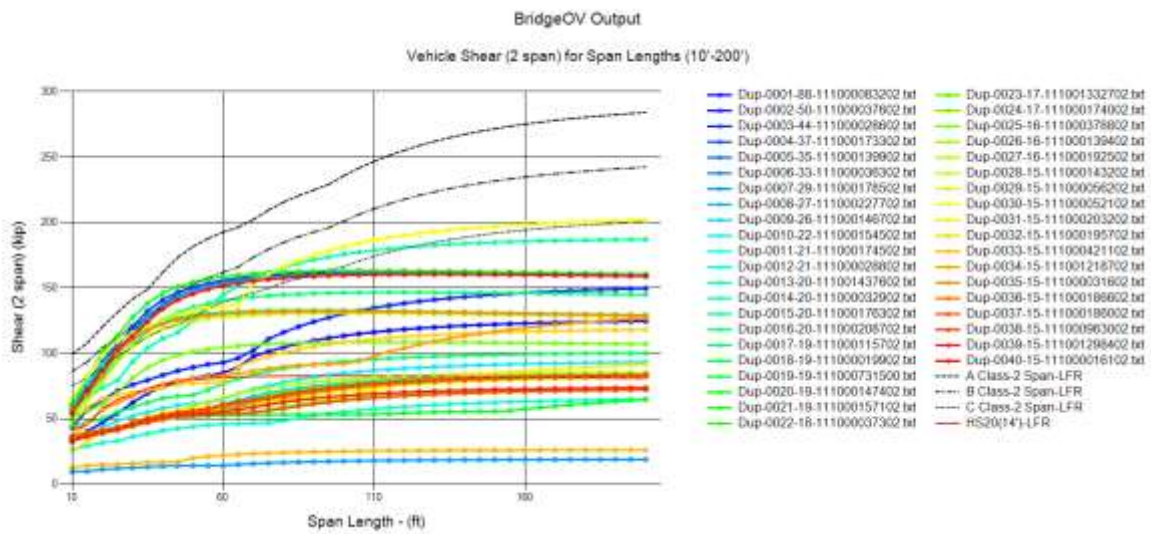


Figure 14. BridgeOV Shear (2-span) for top 40 duplicate vehicles

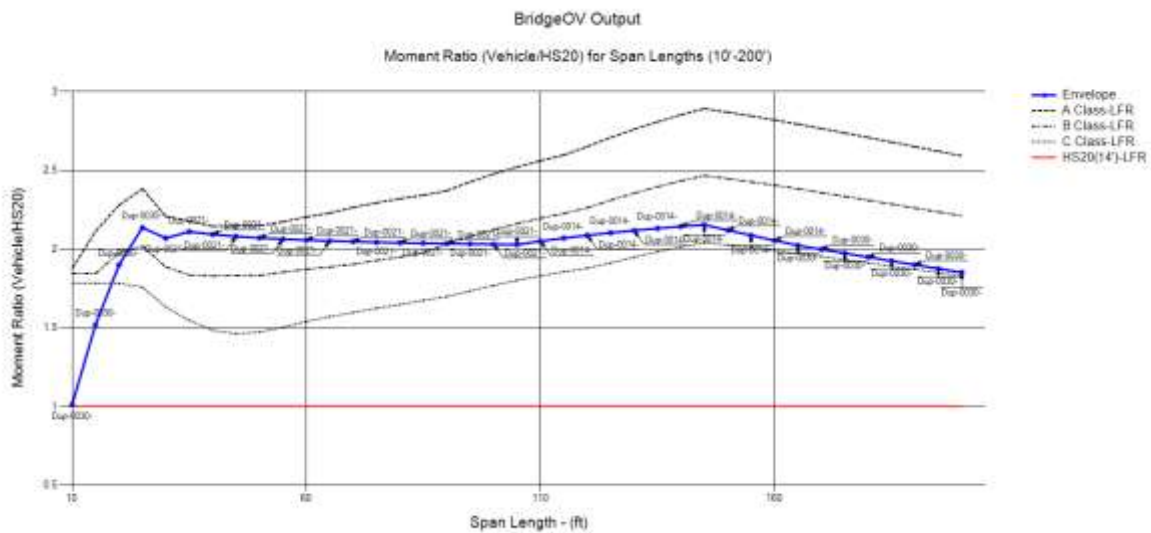


Figure 15. BridgeOV Moment ratio envelope of top 40 duplicate vehicles

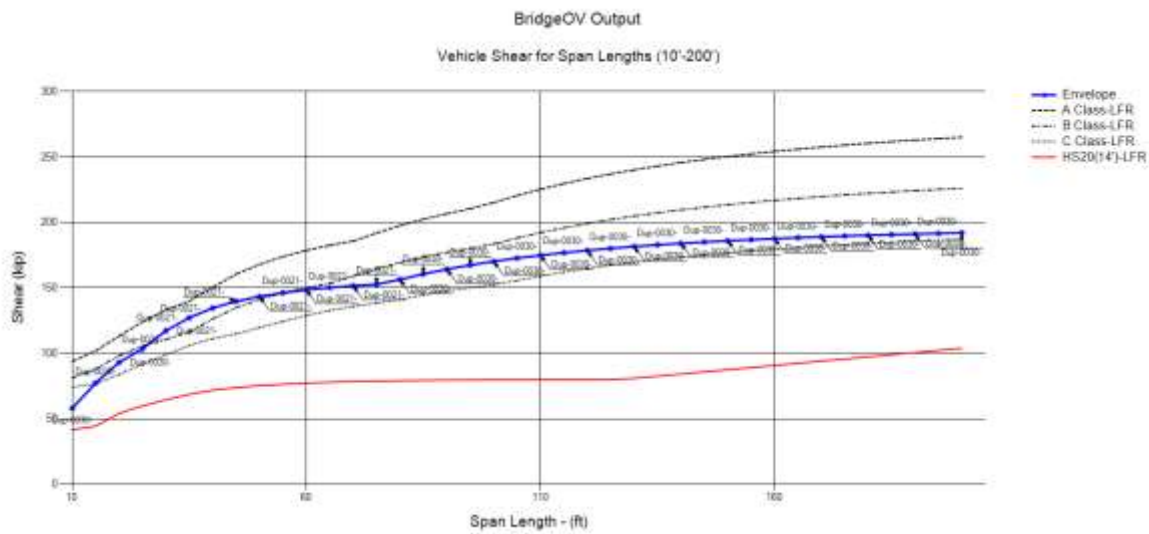


Figure 16. BridgeOV Shear (simple span) envelope for top 40 duplicate vehicles

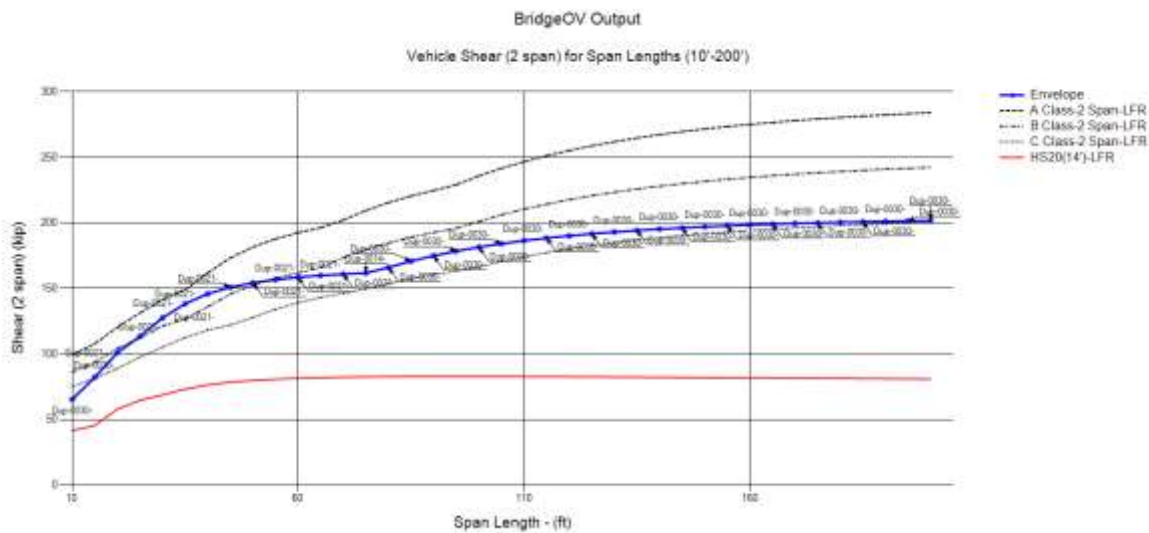


Figure 17. BridgeOV Shear (2-span) envelope for top 40 duplicate vehicles

The figures showing the individual plots (Figure 12, Figure 13, and Figure 14), indicate that several of the vehicles fall below the Class A, B, and C line, while the enveloped figures provide an overall view of these 40 vehicles. Several of the vehicles exceed Class B and C, but none exceed Class A. A summary of the vehicle set and which exceed the class curves are provided in Table 5. The vehicles that exceed at least one span length for 1 class are highlighted in green. Plotting the highlighted vehicles alone yields the moment curve shown in Figure 18, Figure 19, and Figure 20.

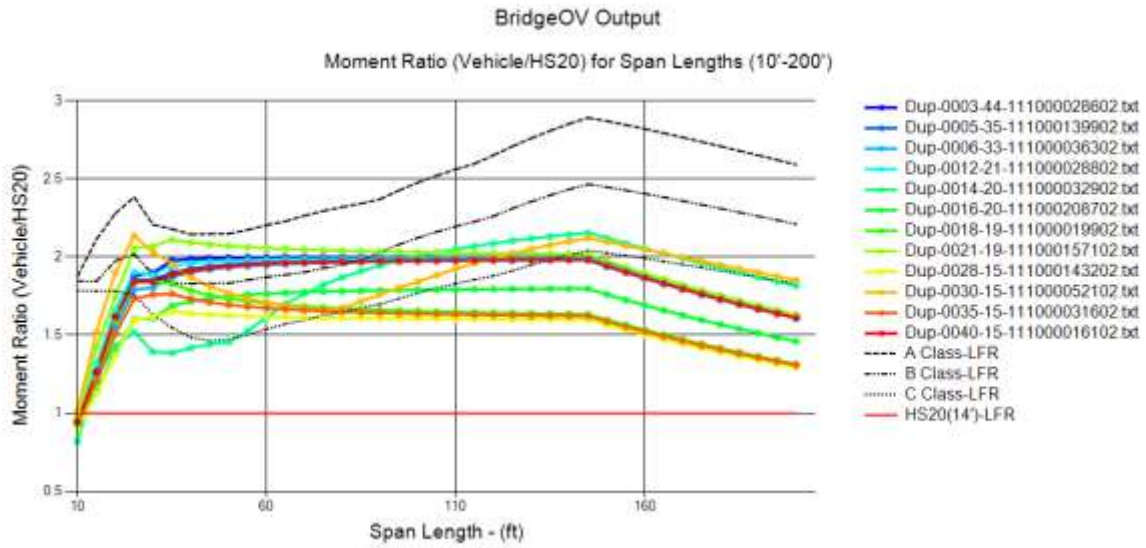


Figure 18. BridgeOV Moment ratio of critical duplicate vehicles

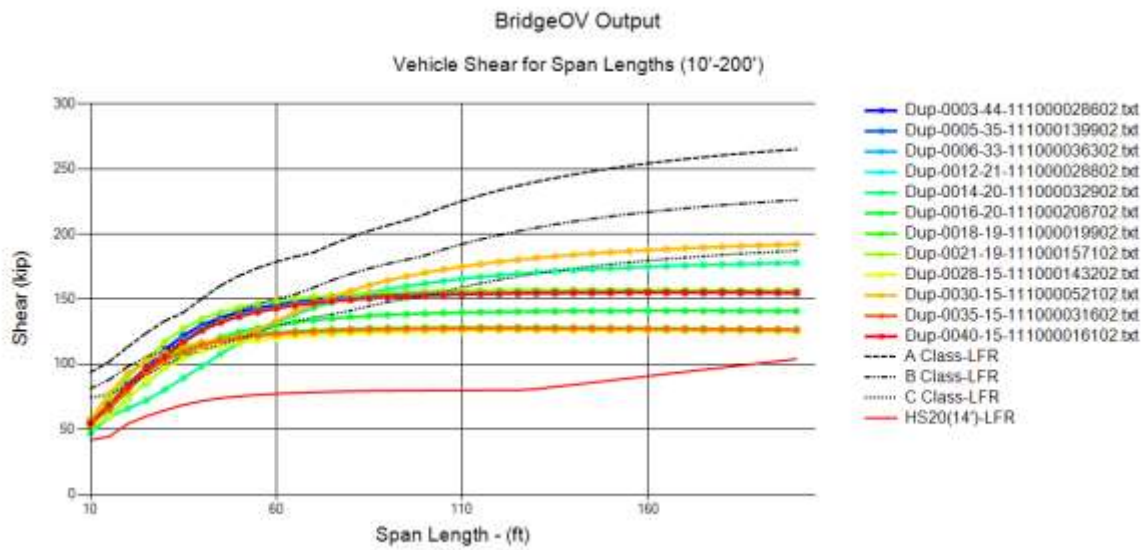


Figure 19. BridgeOV Shear (simple span) for critical duplicate vehicles

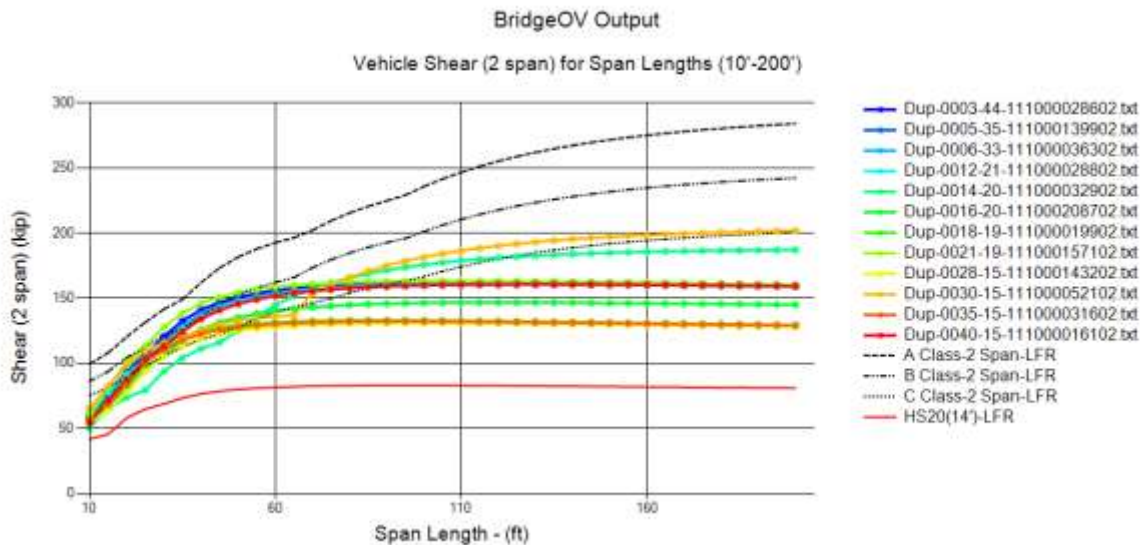


Figure 20. BridgeOV Shear (2-span) for critical duplicate vehicles

The duplicate vehicle analysis represents the vehicles that appear most often in the list provided by TPU. Several of these vehicles exceed Class B and/or Class C allowable values provided by BridgeOV. Using this set as a benchmark, a periodic review (yearly) of this list should be made using the software developed for this project to determine if the overall load (or effects of that load) of the most frequent vehicles allowed in the permitting process remains the same or increases over time. Things to check in the future:

- Do more duplicate vehicles exceed Class B or Class C
- Do duplicate vehicles begin to exceed Class A
- Compare the relative envelope of future permit duplicate vehicles with those shown in Figure 15, Figure 16, and Figure 17.

Using the procedures described in this report and the software delivered with this research, this periodic review can be performed quickly.

Table 5. Review of most frequent vehicle duplicates using BridgeOV

Vehicle ID	Permit ID	Number Duplicates	Num Axles	Gross Weight	Vehicle Length	Exceeds Moment			Exceeds Shear (Simple Span)			Exceeds Shear (2 span)		
						A	B	C	A	B	C	Shear 2-Span A	Shear 2-Span B	Shear 2-Span C
Dup-0001	111000083202	88	8	119.0	67.6									
Dup-0002	111000037602	50	8	146.0	71.7									
Dup-0003	111000028602	44	5	143.5	25.8		x	x		x	x		x	x
Dup-0004	111000173302	37	5	80.0	66.5									
Dup-0005	111000139902	35	5	143.5	27.8		x	x		x	x		x	x
Dup-0006	111000036302	33	5	143.5	27.7		x	x		x	x		x	x
Dup-0007	111000178502	29	4	17.8	50.2									
Dup-0008	111000227702	27	5	80.0	59.0									
Dup-0009	111000146702	26	5	80.0	63.0									
Dup-0010	111000154502	22	6	89.0	56.4									
Dup-0011	111000174502	21	5	80.0	61.0									
Dup-0012	111000028802	21	5	143.5	27.1		x	x		x	x			x
Dup-0013	111001437602	20	5	64.0	70.3									
Dup-0014	111000032902	20	8	175.6	51.9			x			x			x
Dup-0015	111000176302	20	5	80.0	63.0									
Dup-0016	111000208702	20	5	130.3	27.0			x			x			x
Dup-0017	111000115702	19	5	94.0	51.8									
Dup-0018	111000019902	19	4	114.8	17.8			x			x			x
Dup-0019	111000731500	19	5	78.0	141.4									
Dup-0020	111000147402	19	5	80.0	61.6									
Dup-0021	111000157102	19	5	143.5	23.8		x	x		x	x		x	x
Dup-0022	111000037302	18	5	80.0	65.2									
Dup-0023	111001332702	17	5	70.0	65.0									
Dup-0024	111000174002	17	5	80.0	61.8									
Dup-0025	111000378802	16	4	96.0	23.8									
Dup-0026	111000139402	16	5	80.0	65.7									
Dup-0027	111000192502	16	5	80.0	53.7									
Dup-0028	111000143202	15	4	114.4	20.8			x						x
Dup-0029	111000056202	15	5	80.0	68.7									
Dup-0030	111000052102	15	8	193.5	67.1		x	x			x			x
Dup-0031	111000203202	15	9	96.0	93.6									
Dup-0032	111000195702	15	6	112.0	64.8									
Dup-0033	111000421102	15	5	24.0	47.0									
Dup-0034	111001218702	15	9	135.0	98.6									
Dup-0035	111000031602	15	4	114.8	18.7			x			x			x
Dup-0036	111000186602	15	5	80.0	66.9									
Dup-0037	111000186002	15	5	70.0	65.7									
Dup-0038	111000963002	15	5	80.0	62.8									
Dup-0039	111001298402	15	5	70.0	55.0									
Dup-0040	111000016102	15	5	143.5	28.1		x	x		x	x			x

5.1.3 Vehicle Anomalies

During the sorting of the vehicles by axle concentrations (see following section), it was noticed that some apparent anomalies occur in the data provided by MDOT. Table 6 represents vehicles that have an axle spacing less than 1.5'. Similarly, looking at axle loads that appear too small yields permit vehicles with an axle load that less than 1.1 kips (see Table 7)

These values could be the result of the following possibilities

1. Input error
2. Error translating the routing information to the Excel spreadsheet
3. The small spacing or loading provided was intended for some reason
4. Error in translating the Excel spreadsheet provided by MDOT

We have ruled out the second item by manually reviewing the original spreadsheet for each of the permit vehicles shown in Table 6 and Table 7 to verify the spacing and loading. If these values are indeed in error, we recommend that a check be placed in the routing system for consistency (i.e. reasonable upper and lower bounds).

Table 6. Possible errors in axle spacing

Permit ID	Num Axles	Gross Weight	Vehicle Length	Axle Spacing 1	Axle Spacing 2	Axle Spacing 3	Axle Spacing 4	Axle Spacing 5	Axle Spacing 6	Axle Spacing 7	Axle Spacing 8	Axle Spacing 9	Axle Spacing 10
111000844502	6	112.0	48.3	0.50	4.33	35.08	4.17	4.17					
111000949702	11	221.0	78.1	10.50	4.33	4.50	6.42	0.33	35.00	4.17	4.17	4.17	4.50
111001384802	5	72.0	51.0	11.00	1.00	35.00	4.00						
111001935002	6	108.3	57.2	15.17	4.17	33.00	4.50	0.33					
111002178802	9	100.0	91.5	21.50	0.33	14.67	5.00	5.00	35.00	5.00	5.00		

Table 7. Possible errors with axle loads

Permit ID	Num Axles	Gross Weight	Vehicle Length	Axle Spacing 1	Axle Spacing 2	Axle Spacing 3	Axle Spacing 4	Axle Spacing 5	Axle Spacing 6	Axle Load 1	Axle Load 2	Axle Load 3	Axle Load 4	Axle Load 5	Axle Load 6	Axle Load 7
111001973902	4	12	29	10	15	4				5.0	5.0	1.0	1.0			
111002017102	4	10	24	12	8	4				4.0	4.0	1.0	1.0			
111000444902	4	4	20	7	10	3				1.0	1.0	1.0	1.0			
111000666702	4	14.5	33	10	20	3				1.5	1.0	6.0	6.0			
112009528302	4	8	26	10	12	4				3.0	3.0	1.0	1.0			
111000003402	4	6	34	15	15	4				2.0	2.0	1.0	1.0			
111000171102	5	45	52	18	26	4	4			1.0	14.0	10.0	10.0	10.0		
111000483402	5	18.427	19	7	7	2.5	2.5			5.0	1.1	4.1	4.1	4.1		
111001985302	5	10	36	12	18	3	3			3.5	3.5	1.0	1.0	1.0		
111001556202	6	65	57.5	20	4.5	24	4.5	4.5		8.0	12.0	12.0	16.0	16.0	1.0	0.0
111001157102	6	10	36	20	4	4	4	4		5.0	1.0	1.0	1.0	1.0	1.0	0.0
111001103102	7	16	40	20	4	4	4	4	4	10.0	1.0	1.0	1.0	1.0	1.0	1.0
111000914302	7	7.105	72	11	51	2.5	2.5	2.5	2.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0

5.1.4 Axle Concentrations

Vehicles with heavy concentrations of axle load will likely govern shear and/or moment calculations. The PVA software written for this project has the capability to sort through a large number of vehicles to determine the largest 2, 3, 4 and 5 axle concentrations. This process of reviewing short, heavy trucks was performed using the PVA software which calculates the concentration of axles of all permit vehicles submitted by MDOT. The vehicles with the largest 2, 3, 4, and 5 axle concentrations were reviewed and plotted using BridgeOV to try to determine the effects of these vehicles. To determine the vehicle concentration, each set of axles for the whole vehicle is analyzed to determine the largest concentration by distributing those axles over the spacing between them.

For example, for the vehicle shown in Figure 21 the 2 and 3 wheel concentrations would be as shown in Table 8.

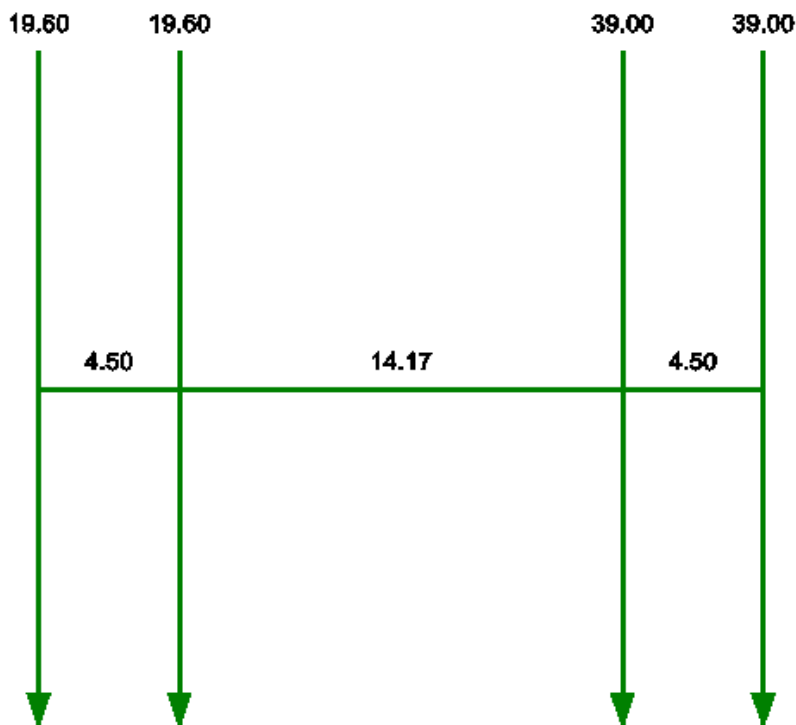


Figure 21. Axle concentration example

Table 8. Calculation of 2 and 3 axle concentrations

2 Axle Concentration	Calculation	Maximum Value
(Axle 1 Load + Axle 2 Load) / Axle 1 Spacing	$(19.6 + 19.6) / 4.5$	8.71
(Axle 2 Load + Axle 3 Load) / Axle 2 Spacing	$(19.6 + 39.0) / 14.17$	4.13
(Axle 3 Load + Axle 4 Load) / Axle 3 Spacing	$(39 + 39) / 4.5$	17.33

3 Axle Concentration	Calculation	Maximum Value
(Axle 1 Load + Axle 2 Load + Axle Load 3) / (Axle 1 Spacing + Axle 2 Spacing)	$(19.6 + 19.6 + 39) / (4.5 + 14.17)$	4.19
(Axle 2 Load + Axle 3 Load + Axle 4) / (Axle 2 Spacing + Axle 3 Spacing)	$(19.6 + 39.0 + 39) / (14.17 + 4.5)$	5.23

5.1.4.1 Two-Axle Concentrations

Using the PVA software, the largest 2-axle concentrations were determined as shown in Table 9.

Table 9. Largest 2-axle vehicle concentrations

Permit ID	Permit #	Number Duplicates	Num Axles	Gross Weight	Vehicle Length	2 axle Conc	3 axle Conc	4 axle Conc	5 axle Conc
111000949702*	2AC-0001	0	11	221.0	78.1	120.00	8.89	7.11	6.47
111001935002*	2AC-0002	0	6	108.3	57.2	112.50	11.64	2.02	2.29
111002178802*	2AC-0003	0	9	100.0	91.5	81.00	3.30	2.15	2.04
111000844502**	2AC-0004	0	6	112.0	48.3	64.00	10.76	1.84	2.09
111001384802***	2AC-0005	0	5	72.0	51.0	32.00	3.33	1.60	1.41
111001324800	2AC-0006	0	9	289.2	89.8	22.09	9.75	8.83	5.15
111000981202	2AC-0007	1	6	165.4	42.0	20.00	15.00	4.44	5.00
111000336602	2AC-0008	1	8	105.0	58.0	18.00	6.67	5.05	1.48
111000073202	2AC-0009	7	4	117.2	23.2	17.33	5.23	5.06	0.00
111001246502	2AC-0010	0	4	114.2	22.8	16.98	5.14	5.00	0.00
111000136102	2AC-0011	1	4	115.0	28.0	16.84	4.06	4.11	0.00
111000345102	2AC-0012	1	4	114.2	23.0	16.67	5.11	4.97	0.00
111000320302	2AC-0013	0	5	71.3	61.0	16.24	3.62	1.43	1.17
111000958902	2AC-0014	0	4	117.6	26.5	16.22	4.52	4.44	0.00
111000469500	2AC-0015	0	8	208.0	70.3	16.12	12.07	10.72	3.35
111000393900	2AC-0016	0	15	480.0	221.4	16.00	8.72	8.53	5.07
111001883502	2AC-0017	0	9	217.6	72.0	15.40	10.70	6.57	6.00
111000273402	2AC-0018	2	6	150.2	29.9	15.20	11.17	5.34	5.16
111000858702	2AC-0019	0	6	127.4	42.0	14.93	11.20	3.32	3.73
111000761002	2AC-0020	0	4	96.0	23.3	14.79	4.42	4.11	0.00
111001569902	2AC-0021	0	7	163.6	56.3	14.78	6.60	5.87	3.26
111000296500	2AC-0022	0	5	111.0	59.9	14.75	3.49	1.97	1.85
111000439302	2AC-0023	3	6	114.3	51.2	14.67	11.00	2.25	2.53
111000898802	2AC-0024	0	6	150.0	61.5	14.62	10.96	2.41	2.78
111000564402	2AC-0025	0	6	145.0	61.5	14.51	10.88	2.39	2.76
111000478902	2AC-0026	1	8	219.0	68.3	14.50	10.35	8.62	2.95
111001046502	2AC-0027	0	6	140.0	63.5	14.29	10.71	2.38	2.75
111000547600	2AC-0028	0	8	163.2	70.3	14.28	10.00	8.43	2.65
111000685100	2AC-0029	0	8	163.2	70.3	14.28	9.99	8.43	2.65
111000122002	2AC-0030	0	9	234.6	72.3	14.22	10.39	7.57	6.84
111002057700	2AC-0031	0	8	161.1	70.3	14.10	9.87	8.32	2.62
*contains an axle spacing of 0.33'									
** Contains an axle spacing of 0.5'									
*** Contains an axle spacing of 1.0'									

Note that the top five axle combinations have some small axle spacings that appear to be suspect. Running BridgeOV using just these 5 vehicles yields the moment/ shear plots shown in Figure 22 and Figure 23. Even though the suspect spacing could yield results that could skew the results of the entire permit set, in this case only one of the

vehicles (2AC-0001) exceeds the Class B and Class C values. The other 4 vehicles fall below the Class A, B, and C allowable curves.

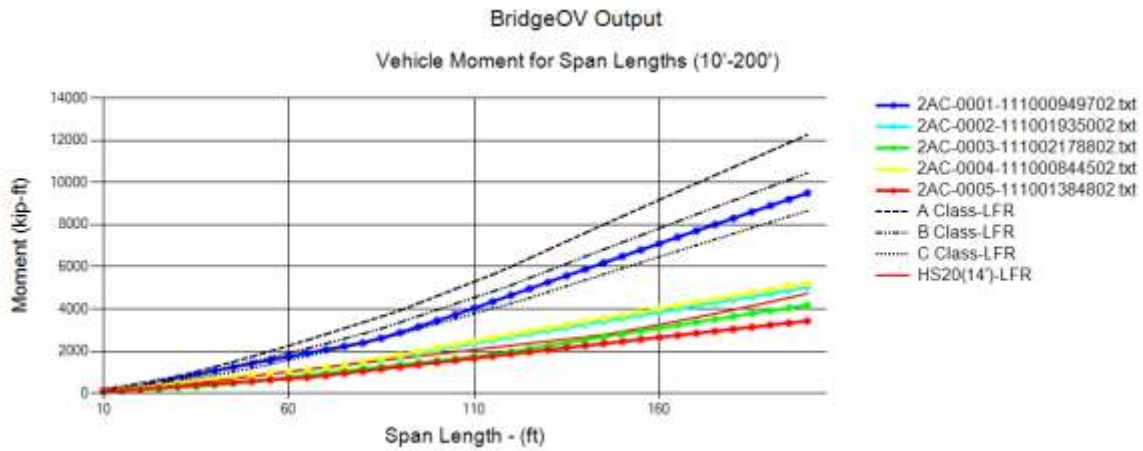


Figure 22. BridgeOV moment - 2 axle concentration- 5 vehicles with suspect axle spacing

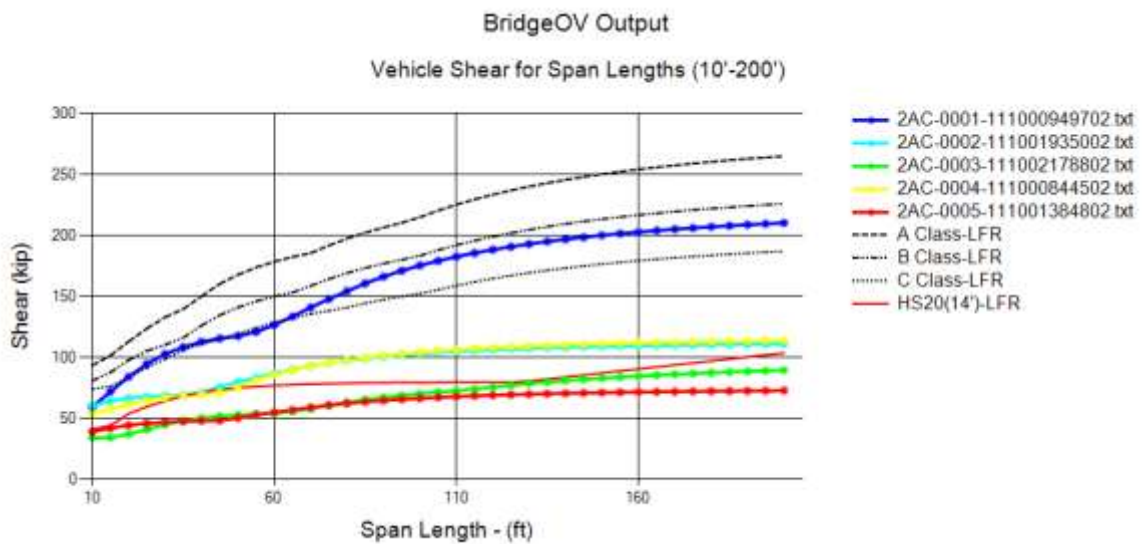


Figure 23. BridgeOV shear – 2-axle concentration- 5 vehicles with suspect axle spacing

Including all 31 vehicles yields the moment plot shown in Figure 24. Reviewing the plots individually, it can be more easily discerned that only vehicles 2AC-0006, 2AC-0015, and 2AC-0016 exceed Class A. Moment and shear plots of these 3 vehicles is shown in Figure 25 and Figure 26.

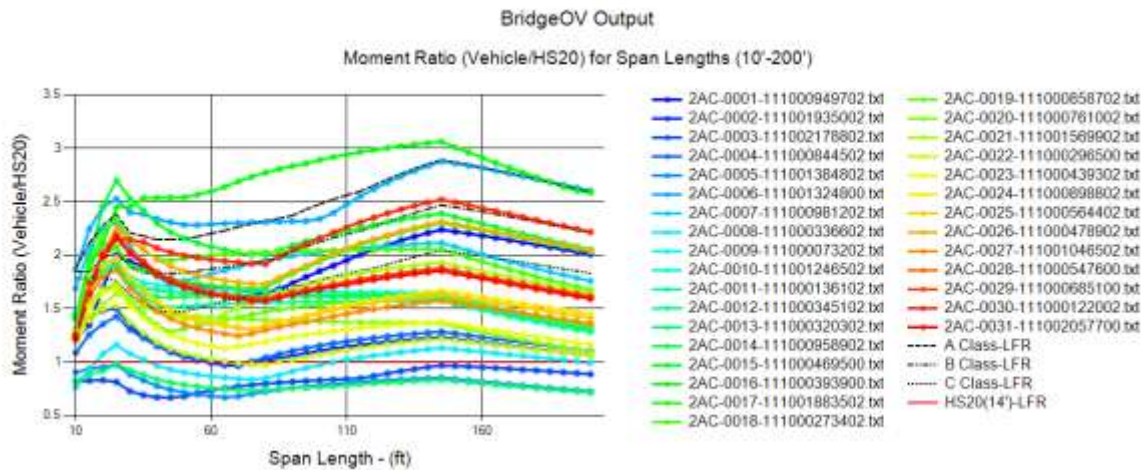


Figure 24. BridgeOV moment plot of all 31 vehicles with 2-axle concentration

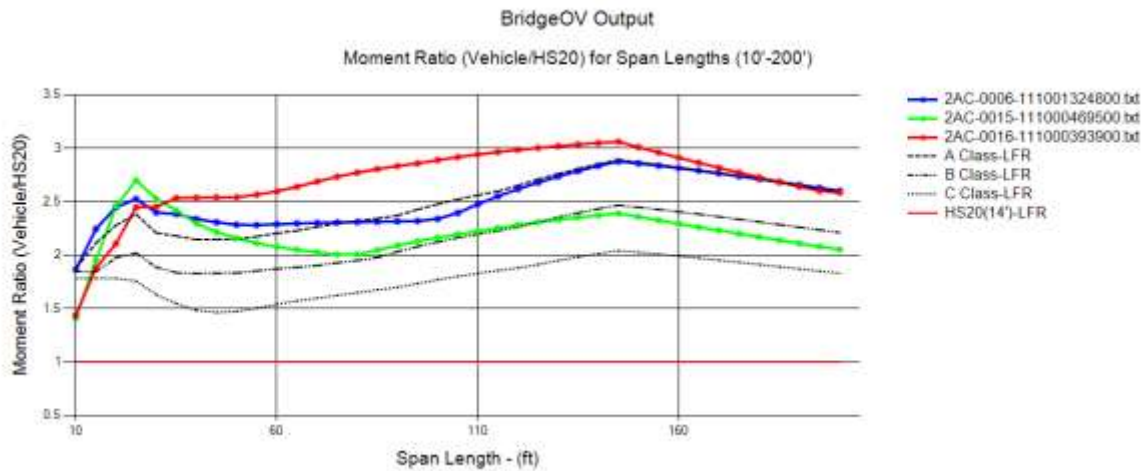


Figure 25. BridgeOV moment plot of Vehicles 2AC-0006, 2AC-0015, and 2AC-0016 2-axle concentration

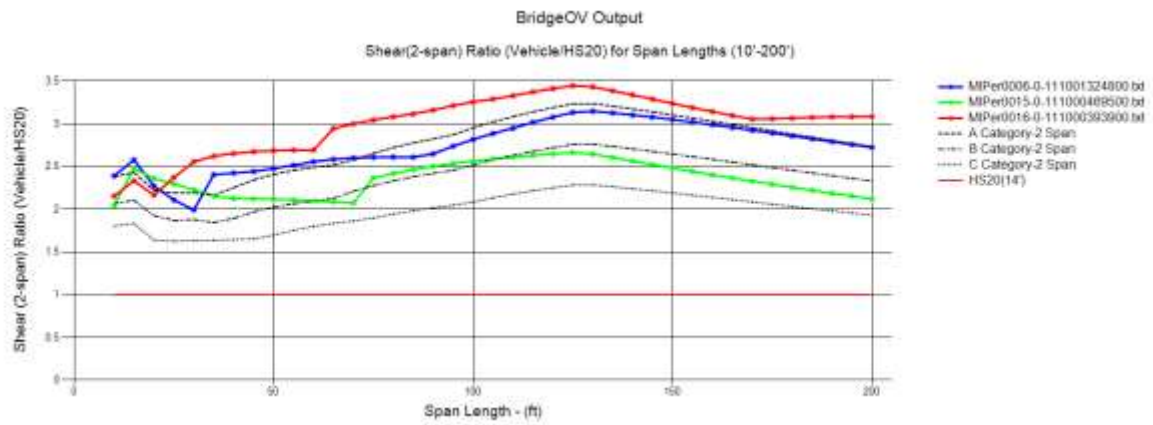


Figure 26. BridgeOV Shear plot of vehicles MiPer0006, MiPer0015, and MiPer0016 2-axle concentration

5.1.4.2 Three-Axle Concentrations

Using the PVA software, the largest 3-axle concentrations were determined as shown in Table 10.

Table 10. Largest 3-axle vehicle concentrations

Permit ID	Permit #	Number Duplicates	Num Axles	Gross Weight	Vehicle Length	2 axle Conc	3 axle Conc	4 axle Conc	5 axle Conc
111000981202	3AC-0001	1	6	165.4	42.0	20.00	15.00	4.44	5.00
111000469500	3AC-0002	0	8	208.0	70.3	16.12	12.07	10.72	3.35
111001935002*	3AC-0003	0	6	108.3	57.2	112.50	11.64	2.02	2.29
111000858702	3AC-0004	0	6	127.4	42.0	14.93	11.20	3.32	3.73
111000273402	3AC-0005	2	6	150.2	29.9	15.20	11.17	5.34	5.16
111000439302	3AC-0006	3	6	114.3	51.2	14.67	11.00	2.25	2.53
111000898802	3AC-0007	0	6	150.0	61.5	14.62	10.96	2.41	2.78
111000564402	3AC-0008	0	6	145.0	61.5	14.51	10.88	2.39	2.76
111000844502**	3AC-0009	0	6	112.0	48.3	64.00	10.76	1.84	2.09
111001046502	3AC-0010	0	6	140.0	63.5	14.29	10.71	2.38	2.75
111001883502	3AC-0011	0	9	217.6	72.0	15.40	10.70	6.57	6.00
111000498502	3AC-0012	0	6	145.0	61.5	14.07	10.55	2.32	2.68
111000180502	3AC-0013	3	7	198.7	64.5	14.09	10.44	9.23	3.08
111000122002	3AC-0014	0	9	234.6	72.3	14.22	10.39	7.57	6.84
111001803102	3AC-0015	0	11	270.0	87.0	13.85	10.38	9.23	5.33
111000478902	3AC-0016	1	8	219.0	68.3	14.50	10.35	8.62	2.95
111000203102	3AC-0017	0	9	217.6	72.3	14.22	10.27	6.57	6.00
111001934702	3AC-0018	0	7	198.8	71.5	13.69	10.27	4.73	2.88
111001594002	3AC-0019	0	8	208.9	71.4	13.64	10.23	9.09	2.92
111000650702	3AC-0020	2	10	270.0	79.7	13.44	10.08	8.96	6.91
111001884202	3AC-0021	0	9	215.6	72.3	14.22	10.03	6.57	6.00
111000440202	3AC-0022	9	8	183.6	68.3	13.40	10.01	8.88	2.62
111000256902	3AC-0023	4	9	244.0	83.0	13.33	10.00	7.47	7.00
111000547600	3AC-0024	0	8	163.2	70.3	14.28	10.00	8.43	2.65
111000685100	3AC-0025	0	8	163.2	70.3	14.28	9.99	8.43	2.65
111000196402	3AC-0026	3	7	156.2	57.0	13.68	9.96	3.25	3.48
111000210802	3AC-0027	2	13	330.0	119.8	13.25	9.94	4.80	5.05
111000318802	3AC-0028	0	8	208.0	69.0	13.56	9.89	7.69	2.82
111000551702	3AC-0029	4	6	156.4	61.9	13.18	9.88	2.46	2.80
111002057700	3AC-0030	0	8	161.1	70.3	14.10	9.87	8.32	2.62
111000902600	3AC-0031	0	8	160.8	70.3	14.07	9.85	8.31	2.61
*contains an axle spacing of 0.33'									
** Contains an axle spacing of 0.5'									

Note that two of the three axle combinations have small axle spacings that appear to be suspect. Note also that both of these vehicles appeared in the two axle concentration table and we have discussed the overall effect of these two vehicles. The envelope of the 31 vehicles for moment and shear are shown in Figure 28 and Figure 29 respectively. Note that for short spans and long spans, the Class A curve is being

exceeded by vehicles 3AC-0002 and 3AC-0027 (see Figure 27). This is more clearly seen in an envelope plot of these vehicles with the points labeled with the controlling vehicle (see Figure 28). This trend continues for the shear curve envelope again with the 3AC-0002 governing for short spans and exceeding the Class A curve and the 3AC-0027 governing for long spans and exceeding the Class A curve (see Figure 29). Note also, that for the longer span structures that the shear is greater than Class A beginning around 160-ft (see Figure 29) while the moment Class A curve is not exceeded until around 225-ft (see Figure 28). This point accentuates the desirability to have both moment and shear checks in BridgeOV.

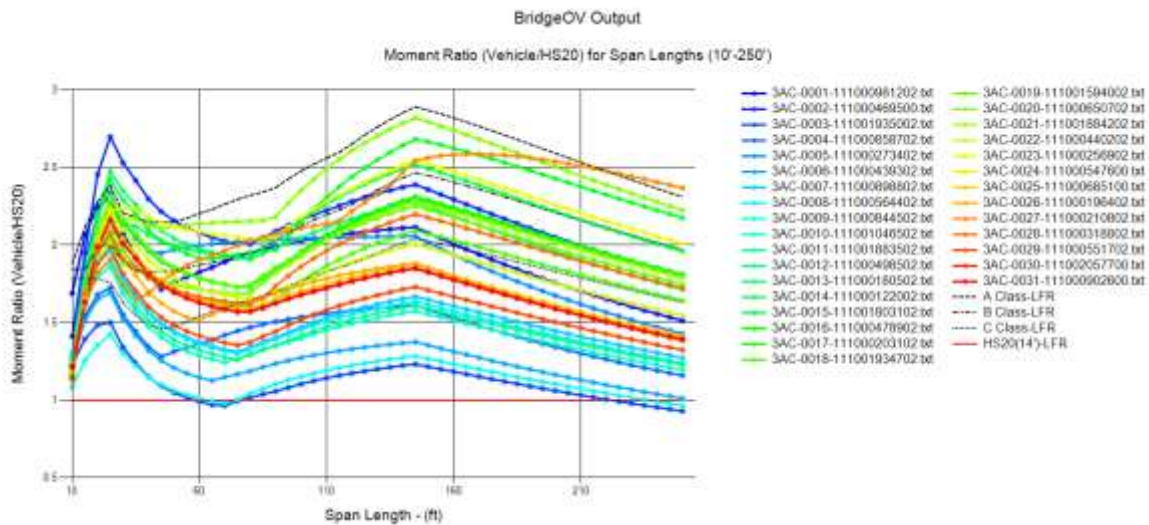


Figure 27. BridgeOV Moment plot of all 31 vehicles with 3-axle concentration

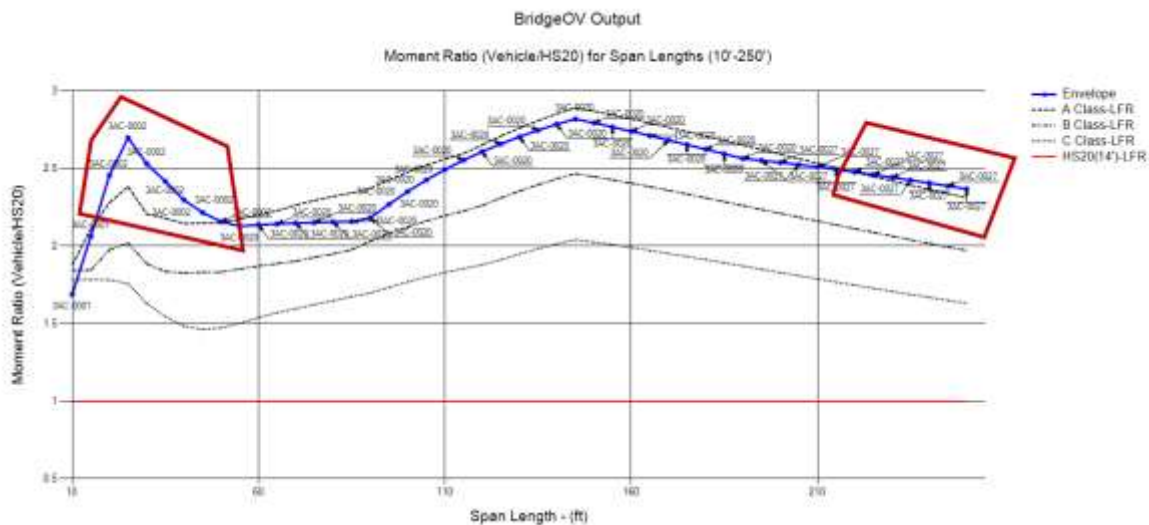


Figure 28. BridgeOV moment plot of 3-axle concentrations – Envelope of top 31 concentrations

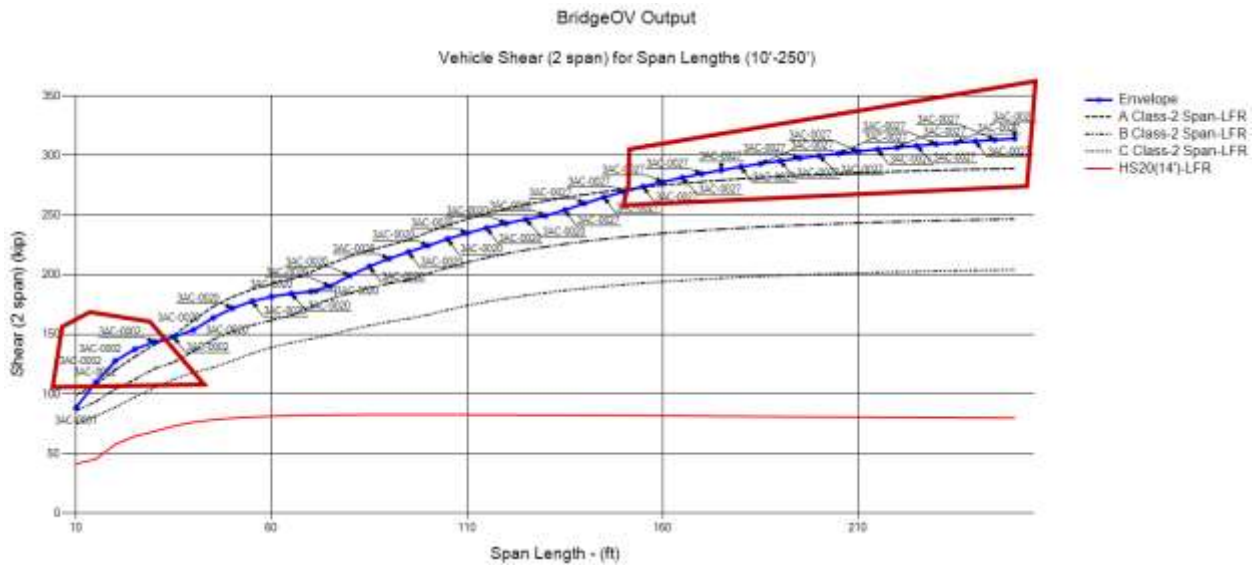


Figure 29. BridgeOV Shear (2-span) plot of 3-axle concentrations – envelope of top 31 concentrations

5.1.4.3 Four-Axle Concentrations

Using the PVA software, the largest 4-axle concentrations were determined as shown in Table 11.

Table 11. Largest 4-axle vehicle concentrations

Permit ID	Permit #	Number Duplicates	Num Axles	Gross Weight	Vehicle Length	2 axle Conc	3 axle Conc	4 axle Conc	5 axle Conc
111000469500	4AC-0001	0	8	208.0	70.3	16.12	12.07	10.72	3.35
111001803102	4AC-0002	0	11	270.0	87.0	13.85	10.38	9.23	5.33
111000180502	4AC-0003	3	7	198.7	64.5	14.09	10.44	9.23	3.08
111001594002	4AC-0004	0	8	208.9	71.4	13.64	10.23	9.09	2.92
111000650702	4AC-0005	2	10	270.0	79.7	13.44	10.08	8.96	6.91
111000440202	4AC-0006	9	8	183.6	68.3	13.40	10.01	8.88	2.62
111001324700	4AC-0007	0	9	277.8	89.8	20.00	9.75	8.83	4.81
111002004302	4AC-0008	0	8	188.0	67.8	14.00	9.75	8.67	2.85
111000202302	4AC-0009	12	9	216.0	74.5	12.96	9.72	8.64	4.32
111000478902	4AC-0010	1	8	219.0	68.3	14.50	10.35	8.62	2.95
111000393900	4AC-0011	0	15	480.0	221.4	16.00	8.72	8.53	5.07
111000267102	4AC-0012	1	10	251.0	84.4	12.73	9.55	8.49	6.14
111000427902	4AC-0013	0	8	222.0	58.5	13.56	9.89	8.44	3.81
111001963802	4AC-0014	0	7	171.3	64.3	12.74	9.55	8.44	2.65
111000547600	4AC-0015	0	8	163.2	70.3	14.28	10.00	8.43	2.65
111000685100	4AC-0016	0	8	163.2	70.3	14.28	9.99	8.43	2.65
111000159802	4AC-0017	14	9	213.0	74.5	12.96	9.72	8.40	4.32
111001738902	4AC-0018	1	8	193.9	71.4	12.59	9.44	8.39	2.70
111002057700	4AC-0019	0	8	161.1	70.3	14.10	9.87	8.32	2.62
111000552802	4AC-0020	3	10	252.0	79.7	12.48	9.36	8.32	6.42
111000902600	4AC-0021	0	8	160.8	70.3	14.07	9.85	8.31	2.61
111001315302	4AC-0022	1	8	196.0	76.7	12.44	9.33	8.30	2.50
111000905002	4AC-0023	0	7	169.2	64.3	12.58	9.41	8.20	2.60
111000181002	4AC-0024	14	7	183.8	71.5	13.54	9.18	8.16	2.52
111001129502	4AC-0025	0	8	180.0	56.0	12.21	9.16	8.14	3.39
111000020202	4AC-0026	1	10	243.0	79.7	12.00	9.00	8.00	6.17
111000052102	4AC-0027	15	8	193.5	67.1	12.00	9.00	8.00	2.78
111000659602	4AC-0028	3	8	202.5	72.8	12.28	8.90	7.91	2.90
111000359302	4AC-0029	0	7	155.2	63.2	11.89	8.85	7.87	2.49
111002138002	4AC-0030	0	10	210.0	65.5	11.76	8.82	7.84	6.76
111000765702	4AC-0031	0	7	172.8	65.0	13.69	8.75	7.78	3.00

Note that none of the four axle combinations have any axle spacings that appear to be suspect. The envelope of the 31 vehicles for shear and moment are shown in Figure 30 and Figure 31. The dominant vehicle in these plots is 4AC-0011 which has a gross weight of 480 kips. Removing this vehicle from the set yields the moment and shear envelope plots shown in Figure 32 and Figure 33. Note that for these plots, many of the spans drop below the Class A curve, however, shorter span bridges are affected with values above the Class A curve.

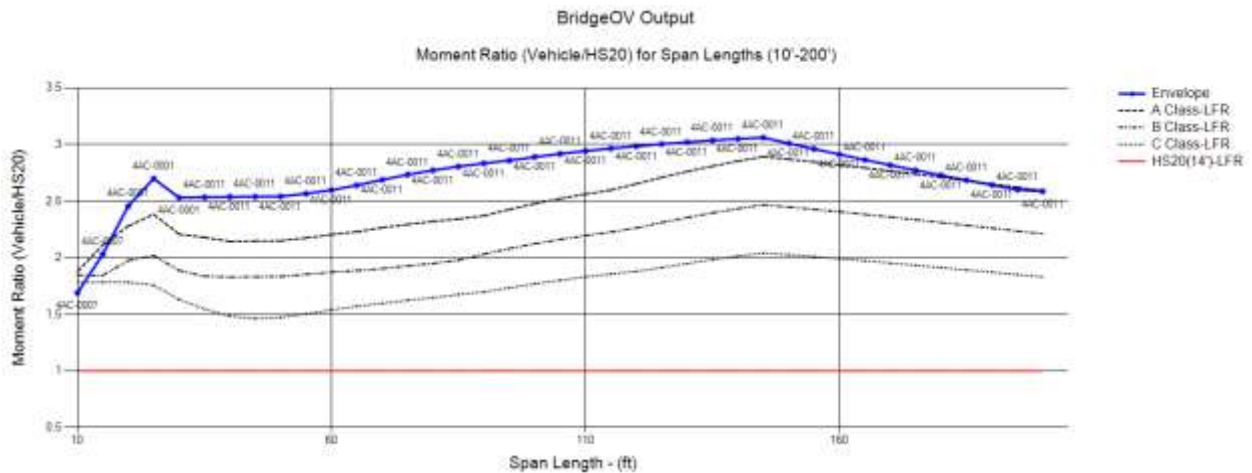


Figure 30. BridgeOV moment plot of 4-axle concentrations – envelope of top 31 concentrations

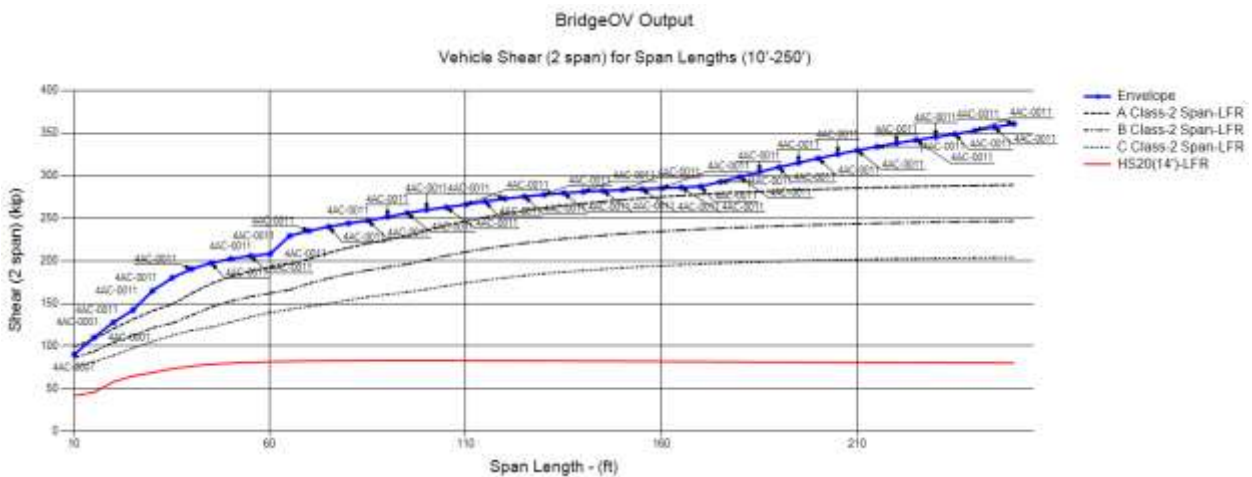


Figure 31. BridgeOV shear plot of 4-axle concentrations – envelope of top 31 concentrations

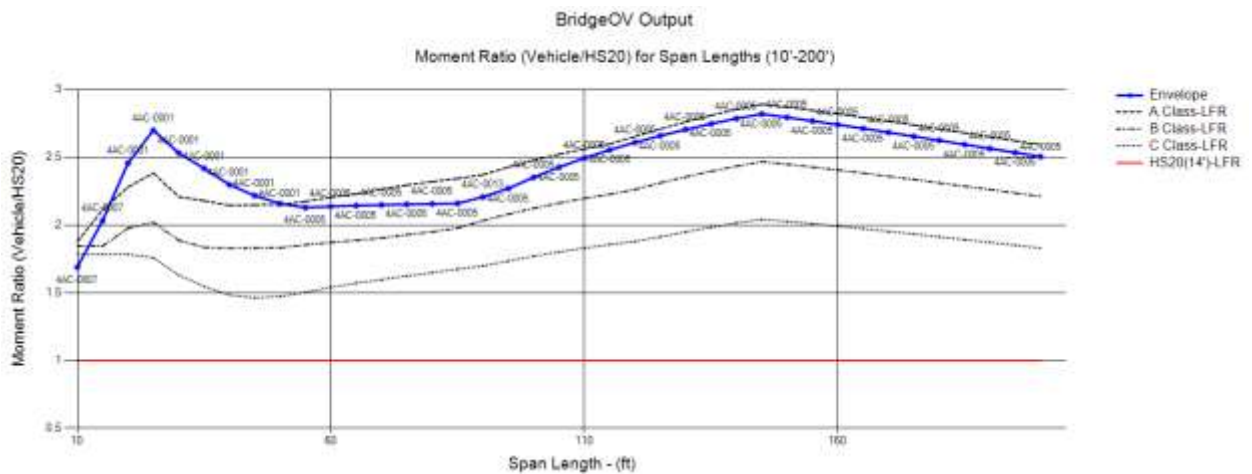


Figure 32. BridgeOV Moment plot of 4-axle concentrations – envelope of top 31 concentrations- W/O 4AC-0011

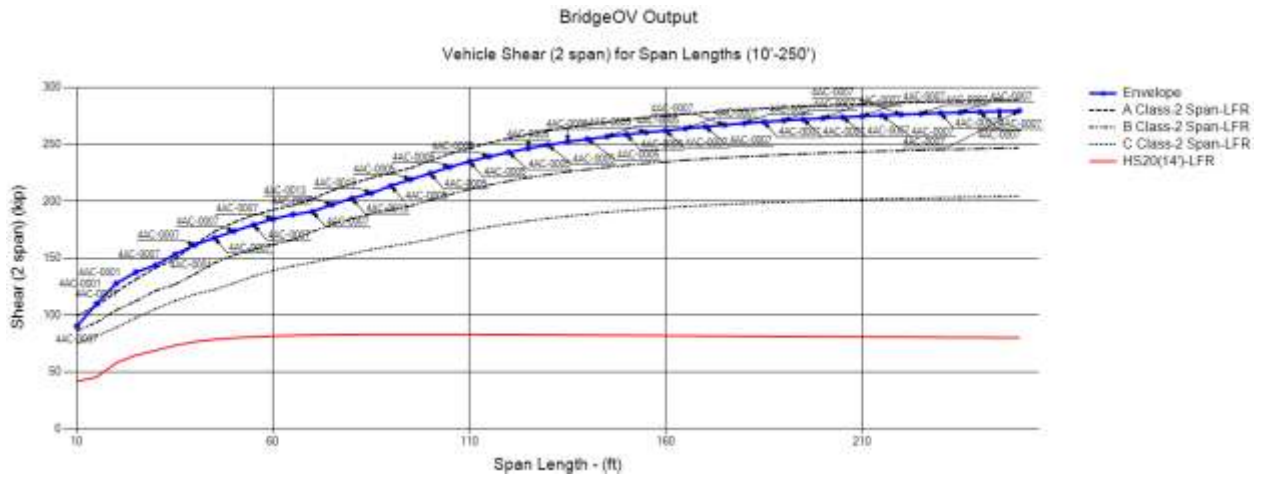


Figure 33. BridgeOV Shear plot of 4-axle concentrations – envelope of top 31 concentrations- W/O 4AC-0011

5.1.4.4 Five-Axle Concentrations

Using the PVA software, the largest 5-axle concentrations were determined as shown in Table 12.

Table 12. Largest 5-axle vehicle concentrations

Permit ID	Permit #	Number Duplicates	Num Axles	Gross Weight	Vehicle Length	2 axle Conc	3 axle Conc	4 axle Conc	5 axle Conc
111000385202	5AC-0001	0	10	261.0	78.2	13.44	9.72	8.64	8.10
111001128702	5AC-0002	1	11	257.0	81.7	12.00	9.00	8.00	7.35
111000020702	5AC-0003	0	11	242.0	81.7	11.52	8.64	7.68	7.20
111001786402	5AC-0004	1	11	271.5	89.3	11.33	8.50	7.56	7.08
111000029902	5AC-0005	0	11	242.0	82.4	11.52	8.64	7.68	7.06
111000256902	5AC-0006	4	9	244.0	83.0	13.33	10.00	7.47	7.00
111000650702	5AC-0007	2	10	270.0	79.7	13.44	10.08	8.96	6.91
111001991702	5AC-0008	0	10	225.0	78.2	11.52	8.28	7.36	6.90
111000122002	5AC-0009	0	9	234.6	72.3	14.22	10.39	7.57	6.84
111002067902	5AC-0010	1	10	246.5	79.5	13.20	8.17	7.26	6.81
111002138002	5AC-0011	0	10	210.0	65.5	11.76	8.82	7.84	6.76
111001493402	5AC-0012	0	10	222.5	78.2	11.52	8.10	7.20	6.75
111000701002	5AC-0013	1	10	261.0	79.7	12.96	9.72	8.64	6.67
111000102202	5AC-0014	0	11	234.0	84.0	10.67	8.00	7.11	6.67
111000296202	5AC-0015	0	11	238.0	86.2	10.56	7.92	7.04	6.60
111000235302	5AC-0016	0	9	195.0	73.9	11.52	8.31	7.04	6.57
111000132802	5AC-0017	0	11	239.0	83.4	11.52	8.31	7.14	6.53
111000165802	5AC-0018	1	11	221.0	82.9	10.56	7.92	7.04	6.47
111001513802	5AC-0019	0	8	190.0	78.4	12.24	7.71	6.86	6.43
111000242702	5AC-0020	0	9	211.0	72.5	12.00	8.71	7.14	6.42
111000552802	5AC-0021	3	10	252.0	79.7	12.48	9.36	8.32	6.42
111000343802	5AC-0022	0	10	216.0	78.2	11.00	7.62	6.77	6.35
111001507302	5AC-0023	0	10	211.0	78.2	11.04	7.56	6.72	6.30
111000028002	5AC-0024	3	7	200.9	37.9	10.60	7.95	6.59	6.28
111000855900	5AC-0025	0	11	227.0	84.4	10.08	7.44	6.64	6.24
111001761202	5AC-0026	0	11	235.0	85.5	10.67	8.00	6.81	6.22
111000719302	5AC-0027	0	10	237.0	88.3	12.00	9.00	6.65	6.22
111000370702	5AC-0028	2	9	208.0	74.5	11.54	8.65	6.57	6.19
111000020202	5AC-0029	1	10	243.0	79.7	12.00	9.00	8.00	6.17
111002038102	5AC-0030	2	10	194.0	122.6	9.86	7.39	6.57	6.16
111001733502	5AC-0031	0	8	150.0	66.3	9.86	7.39	6.57	6.16

Note that none of the five axle combinations have any axle spacings that appear to be suspect. The envelope of the 31 vehicles for shear and moment are shown in Figure 34 and Figure 35. Note that the dominant vehicle in the 4 axle set is no longer present (480 kip gross weight). From Figure 34 it is evident that vehicle 5AC-0001 governs for shorter spans (and exceeds the Class A allowable curve), vehicle 5AC-0024 governs the middle span length ranges (and also exceeds the Class A allowable curve), and vehicle 5AC-0007 governs the longer spans but are within the Class A allowable curve.

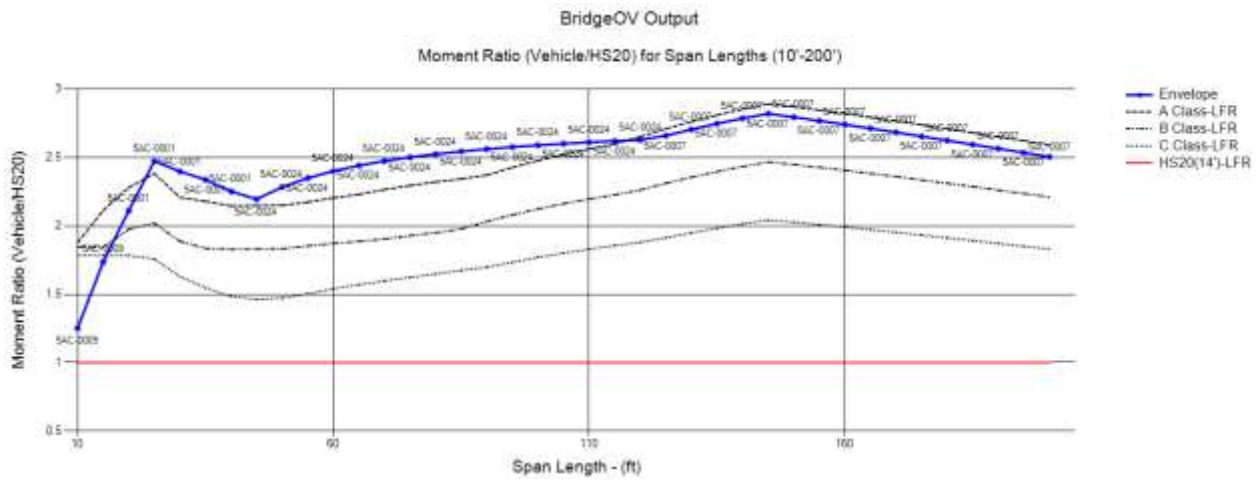


Figure 34. BridgeOV Moment plot of 5-axle concentrations – envelope of top 31 concentrations

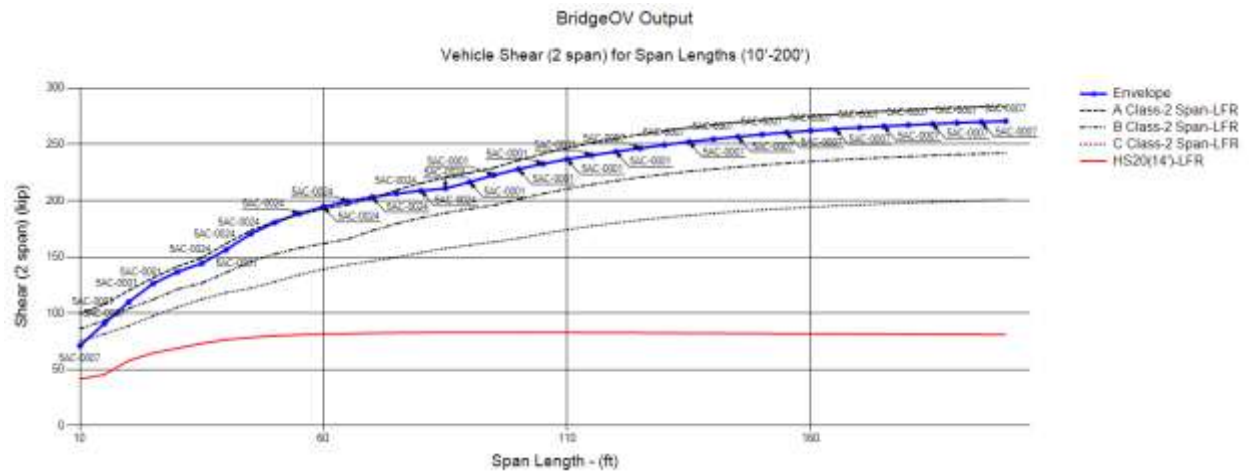


Figure 35. BridgeOV Shear plot of 5-axle concentrations – envelope of top 31 concentrations

5.1.4.5 Maximum Gross Weight

Using the PVA software, the largest gross weight vehicles were determined as shown in Table 13.

Table 13. Largest gross-weight vehicle

Permit ID	Permit #	Number Duplicates	Num Axles	Gross Weight	Vehicle Length
111000393900	GW-0001	0	15	480	221.4167
112009499200	GW-0002	0	19	444	176.0833
111001988700	GW-0003	0	19	426	178.3333
111001443100	GW-0004	0	20	422	199.4167
111001079000	GW-0005	0	18	411.2	150.5833
111001043500	GW-0006	0	19	394	181.5
111001466602	GW-0007	0	19	375.986	146
111002157802	GW-0008	0	18	352	147.3333
111001850502	GW-0009	1	18	335	146.5
111000210802	GW-0010	2	13	330	119.75
111000799002	GW-0011	0	19	318	146.25
111000290502	GW-0012	2	13	306	119.75
111001324800	GW-0013	0	9	289.2	89.83334
111001579800	GW-0014	0	13	279	162
111001324700	GW-0015	0	9	277.8	89.83334
111001731202	GW-0016	0	10	277.5	84.83333
111001131102	GW-0017	2	14	276	126.0833
111000695902	GW-0018	0	13	276	118.5
111000360200	GW-0019	8	13	275	163.3333
111001570300	GW-0020	0	13	273	163.4167
111001570500	GW-0021	0	13	273	164.25
111001970102	GW-0022	0	13	272	124.0833
111001786402	GW-0023	1	11	271.5	89.33333
111000650702	GW-0024	2	10	270	79.66666
111001803102	GW-0025	0	11	270	87.00001
111002199300	GW-0026	0	13	269	164.25
111001578400	GW-0027	0	13	269	165.75
111001365502	GW-0028	2	13	267	133
111001341302	GW-0029	0	13	267	135.6667

The envelope of the 30 vehicles for shear and moment are shown in Figure 36 and Figure 37. Reviewing these plots shows that several vehicles govern, depending on the span lengths. The dominant vehicles are GW-0001, GW-0005 (longer spans), GW-0013 (shorter spans), and GW-0002 (longer spans for shear).

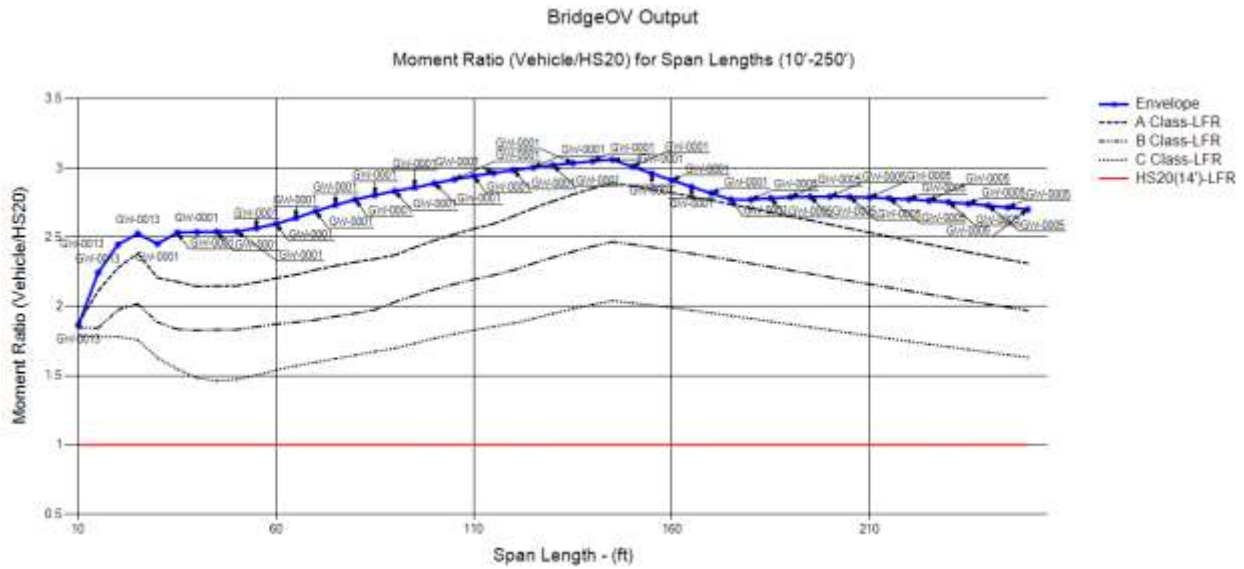


Figure 36. BridgeOV moment plot largest gross-weight vehicles – Top 30

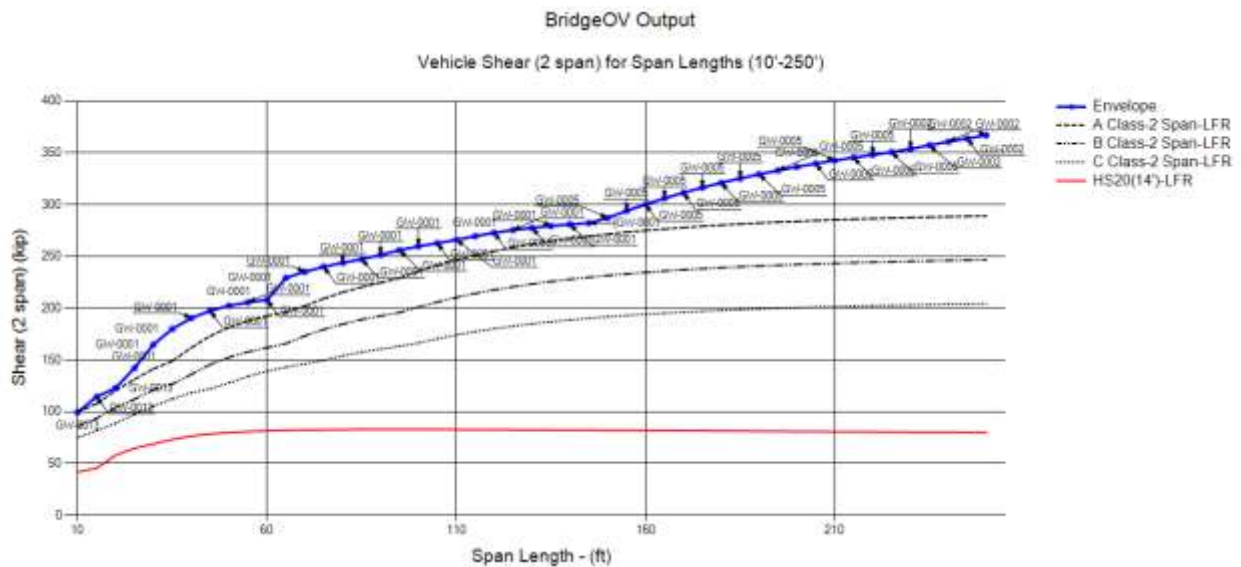


Figure 37. BridgeOV Shear plot largest gross-weight vehicles – Top 30

Plotting each vehicle individually in the BridgeOV software indicates that 9 vehicles exceed the Class A curve; GW-0001, GW-0002, GW-0003, GW-0004, GW-0005, GW-0007, GW-0010, GW-0013, and GW-0025. The plot for these curves for moment and shear are shown in Figure 38 and Figure 39. Note that for both the moment and the shear, at higher span lengths, several of the vehicles begin to diverge from the Class A curve, an indicator that reviewing longer span lengths when appropriate would be necessary.



Figure 38. BridgeOV Moment plot for vehicles GW-0001, GW-0002, GW-0003, GW-0004, GW-0005, GW-0007, GW-0010, GW-0013, and GW-0025

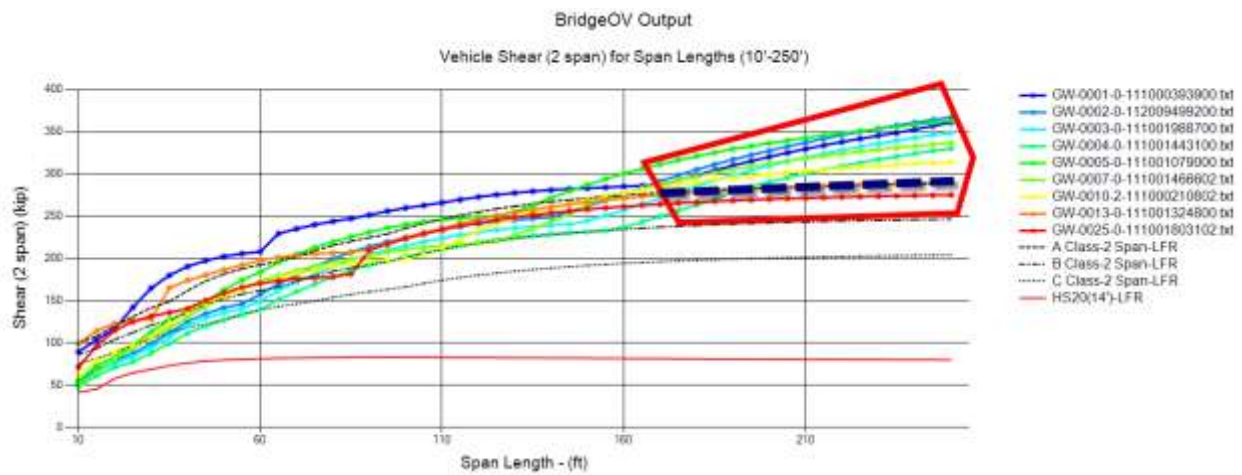


Figure 39. BridgeOV Shear plot for vehicles GW-0001, GW-0002, GW-0003, GW-0004, GW-0005, GW-0007, GW-0010, GW-0013, and GW-0025

5.1.4.6 Five-Axle Construction Vehicle

At MDOT’s request, the researchers reviewed a 5 axle vehicle with 4-ft axle spacing and 24 kip loads for each axle. This emulates the worst possible theoretical construction vehicle that meets the requirements of an MDOT Extended Permit and yields the Moment and Shear plots shown in Figure 40 and Figure 41. Neither of these exceed the Class A curves in BridgeOV but there is some concern in that the moment for shorter spans does exceed the Class B (25-ft – 60-ft) and C (20-ft – 100-ft) curves.

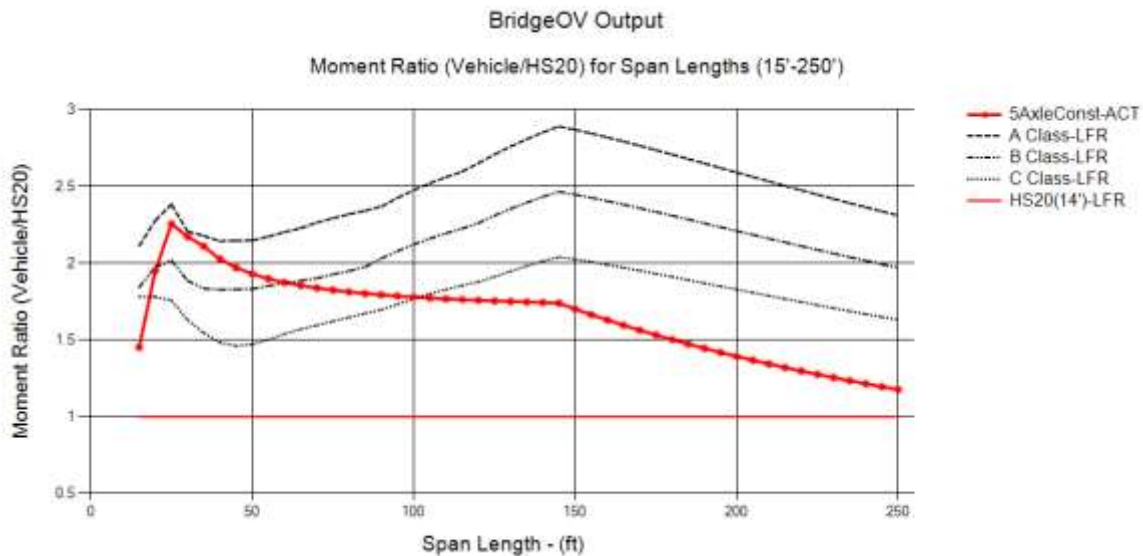


Figure 40. BridgeOV moment plot – 5-axle short vehicle, 24 kip axle loads, 4-ft spacings

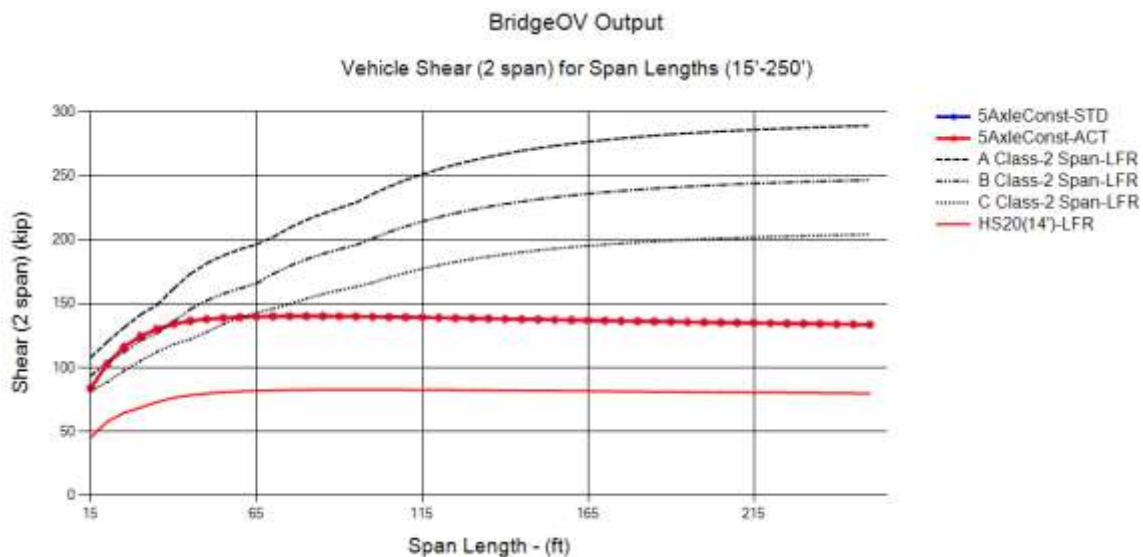


Figure 41. BridgeOV shear plot – 5-axle short vehicle, 24 kip axle loads, 4-ft spacings

5.1.5 Review of Michigan Overload Vehicles (LFR)

Reviewing all of the Class A Michigan overload vehicles in BridgeOV using the LFR option for span lengths of 10-ft – 250-ft and plotting them as an envelope yields the Moment in Figure 42. The labels have been turned on to show which of the overload vehicles governed at each span location. Similar runs were made for both the shear and 2-span shear in order to determine which vehicles governed for each effect at 5-ft span increments. A summary of the governing vehicles per effect is shown in Table 14.

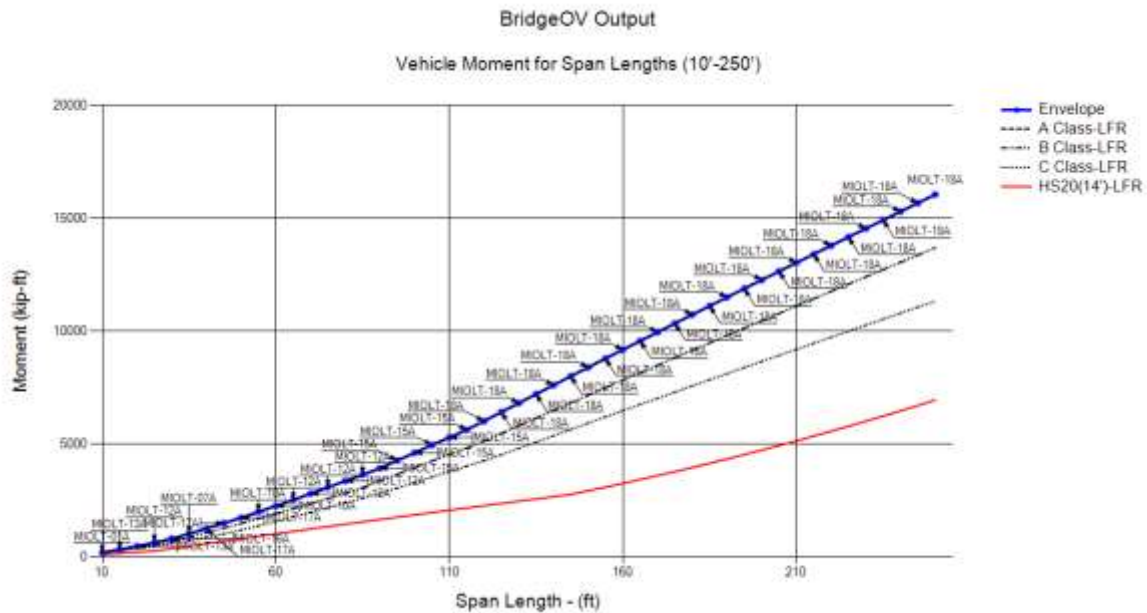


Figure 42. BridgeOV moment plot for Michigan Class A vehicles – governing vehicles labeled

The table reveals that 7 vehicles do not govern any of the effects (2, 3, 4, 6, 8, 11, 19 and 20). Furthermore, vehicle MIOLT-01A only governs for moment for a 10’ span length. The following sections provide a review and recommendations for each of these vehicles.

Table 14. BridgeOV governing Michigan overload vehicles - Class A

Vehicle	Moment	Shear	2 Equal Span Shear
MIOLT-01A	X*		
MIOLT-02A			
MIOLT-03A			
MIOLT-04A			
MIOLT-05A		X	X
MIOLT-06A			
MIOLT-07A	X	X	X
MIOLT-08A			
MIOLT-09A			X
MIOLT-10A	X		
MIOLT-11A			
MIOLT-12A	X	X	X
MIOLT-13A	X		X
MIOLT-14A	X		
MIOLT-15A	X	X	X
MIOLT-16A	X	X	
MIOLT-17A	X	X	
MIOLT-18A	X	X	X
MIOLT-19A			
MIOLT-20A			

*Note: MIOLT-01A only governs at the 10' span length

5.1.5.1 Overload Vehicles 1 through 5

In reviewing the Class A vehicles provided by MDOT, the first 5 Class A vehicles are 2 axle vehicles with two 60 kip loads. The spacings between the two axles are shown in Table 15.

Table 15. Spacing of Michigan 2-axle overload Class A vehicles

2 Axle Vehicle	Spacing between 2 axles (feet)	Axle Weight (kips)
MIOLT-01A	30	60
MIOLT-02A	25	60
MIOLT-03A	20	60
MIOLT-04A	14	60
MIOLT-05A	11	60

Running these vehicles in BridgeOV yields the shear and moment curves shown in Figure 43 and Figure 44. The curves indicate the possibility of eliminating Overload Vehicles 1 through 4 from the set. These could possibly be used for checks in the negative moment region however, which BridgeOV does not currently calculate. The plots do indicate that for simple span structures, these vehicles could likely be ignored when running Virtis for span lengths greater than 25-ft as even the shear drops off dramatically from the Class A curve beyond that span length.

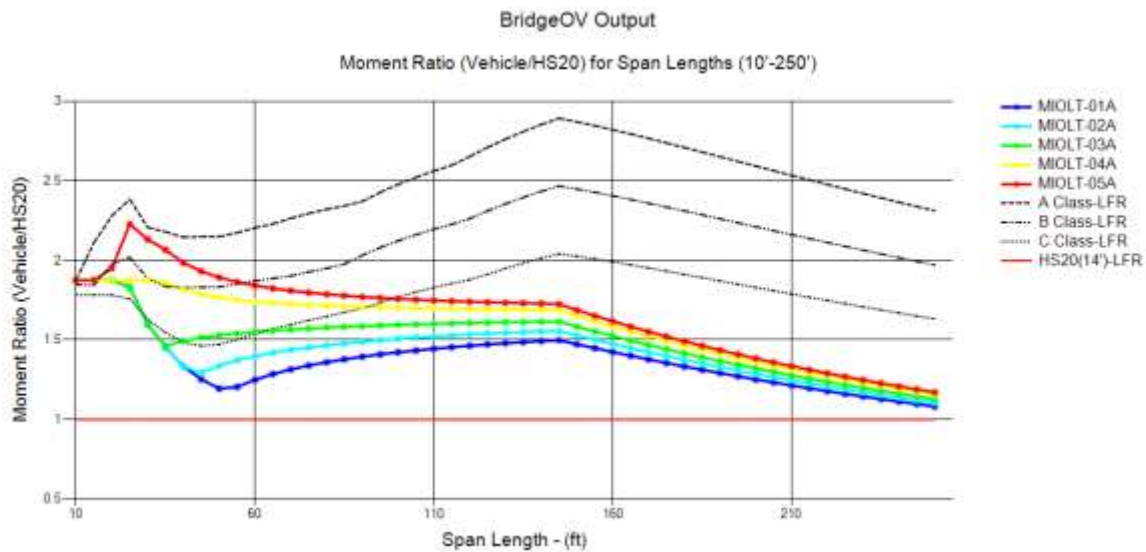


Figure 43. BridgeOV Moment plot of 2-axle Michigan overload vehicles

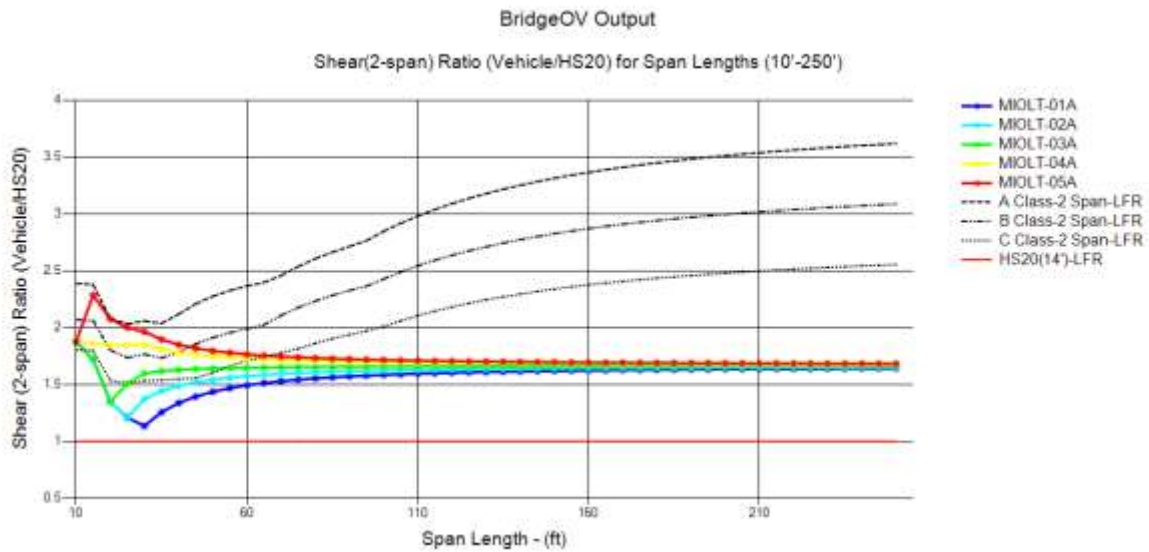


Figure 44. BridgeOV shear (2 span) plot of 2-axle Michigan overload vehicles

5.1.5.2 Overload Vehicles 6 and 8

Vehicles 6 and 8 do not govern for any effect, however, the results for short span ranges are close enough to the Class A curve for moment, that they should be retained. (see Figure 45).

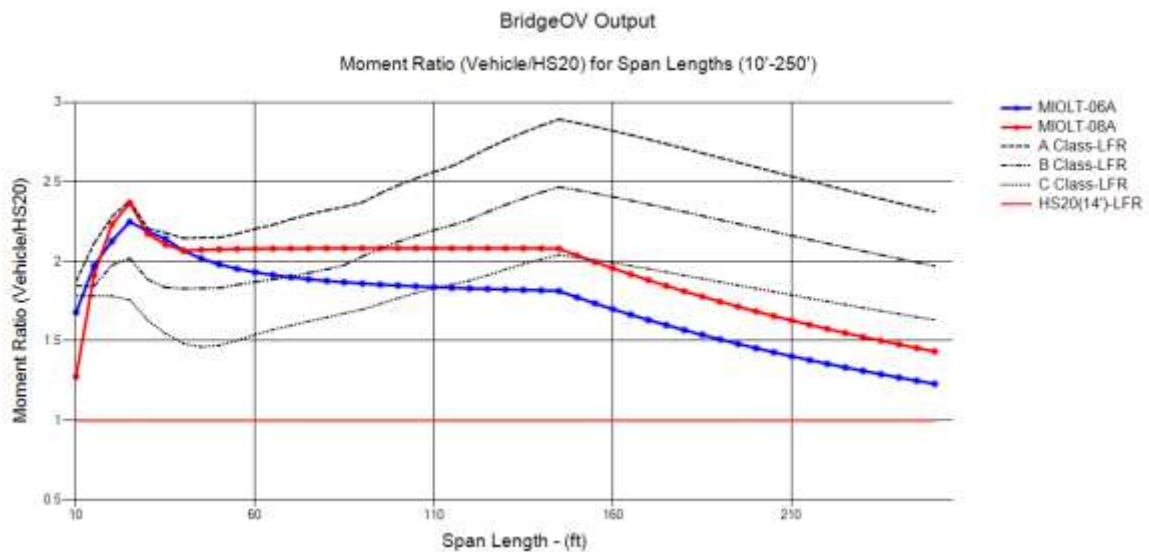


Figure 45. BridgeOV moment plots – Class A- vehicles 6 and 8

5.1.5.3 Overload Vehicles 11, 19 and 20

Vehicles 11, 19, and 20 do not govern for any effect (see Figure 46, Figure 47 and Figure 48). The MIOLT-20A truck comes close for short spans for the moment effect, but several other overload vehicles do as well. It is recommended that these vehicles be reviewed to be for possible removal from the set.

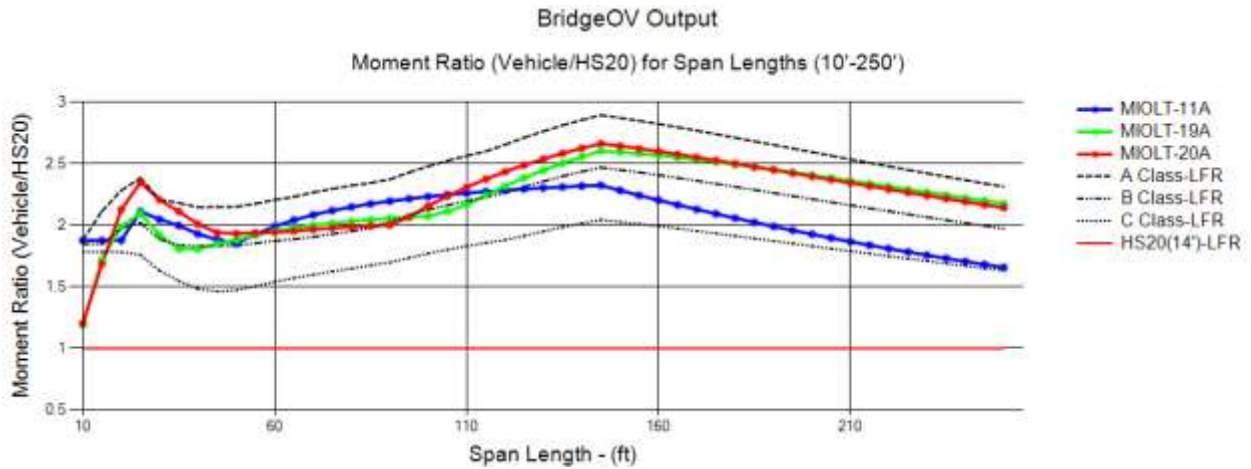


Figure 46. BridgeOV moment plots – Class A- vehicles 11, 19 and 20

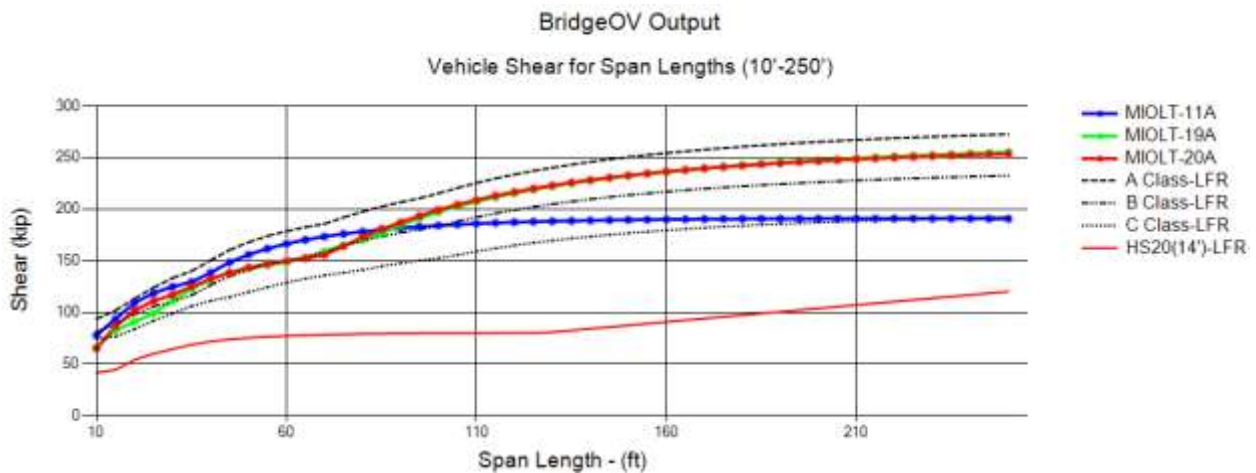


Figure 47. BridgeOV shear plots – Class A- vehicles 11, 19 and 20



Figure 48. BridgeOV shear-2-span plots – Class A- vehicles 11, 19 and 20

5.1.6 Review of NBI Maximum Span Length

Using some of the permit vehicles delivered from MDOT, a review was made of the possibility/ practicality of using the NBI item number 48 (length of maximum span) to set the maximum span length used by BridgeOV. In general, the maximum span length cannot be used conservatively with BridgeOV except as possibly an upper bound. If the NBI bridge record has multiple spans and the upper span length is used (or a range near the upper span length), spans within the same bridge with shorter span lengths would be missed. In some cases, BridgeOV will fail bridges with shorter span lengths, but pass bridges with longer span lengths. Figure 49 shows an example from the MDOT permit set for two-axle concentrations (2AC-0015).

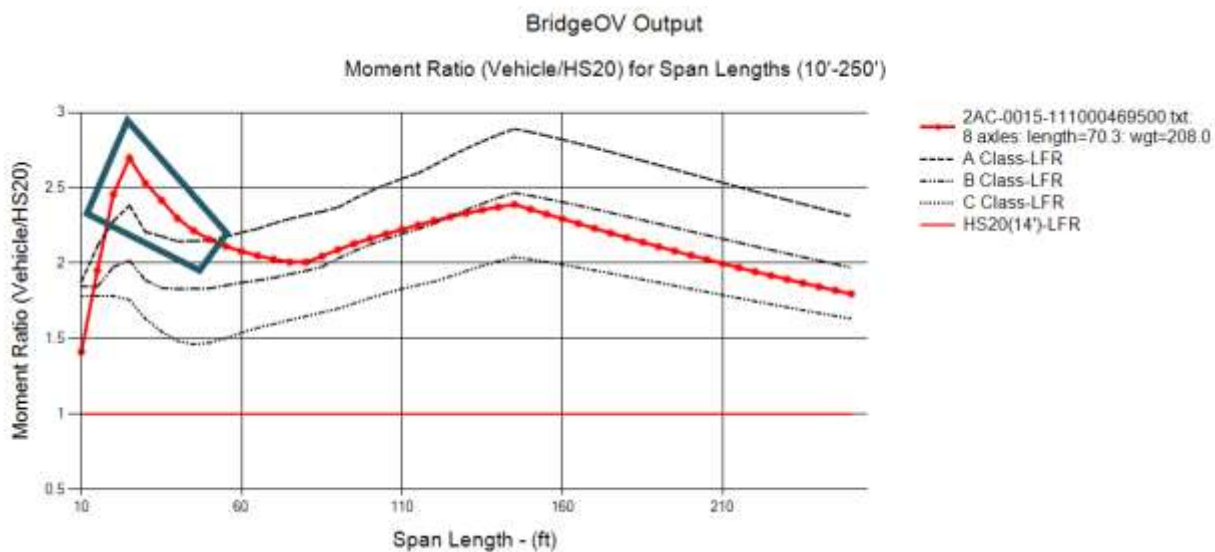


Figure 49. Bridge failing BridgeOV for shorter span length but passing for longer span lengths

If the length of maximum span item is considered as an upper bound for Bridge OV, some longer vehicles that fail for longer spans, would benefit from an upper bound based on the length of maximum span. The largest (and longest vehicle) from the permit set provided in the MDOT permit set has a gross weight of 480 kips and a length of 221.4-ft with a maximum axle load of 46 kips. This vehicle was slightly modified by decreasing the axle loads from 46 kips to 38 kips to demonstrate the case where the moments/ shears for shorter span bridges may pass BridgeOV while longer spans would fail. The revised vehicle is shown in Figure 50. The moment and shear plots for the vehicle are shown in Figure 51 and Figure 52. In the shear plot (Figure 51), BridgeOV passes class A for shear up to about the 225-ft span length, but then starts failing Class A. For the moment plot, BridgeOV passes the Class A for spans up to 250-ft, but at 250-ft is trending upward. Two points arise from this:

- Using a maximum span length value from the NBI record for BridgeOV would safely allow passage on bridges with only shorter span members while appropriately blocking the issuing of permits for the few longer span bridges. This method is recommended and is incorporated in the final software package produced for this research project
- Longer span lengths (up to 250-ft) have been incorporated into BridgeOV to account for longer vehicles that cannot be analyzed in Virtis.



Figure 50. Revised permit vehicle – maximum axle loads changed from 46 kips to 38 kips

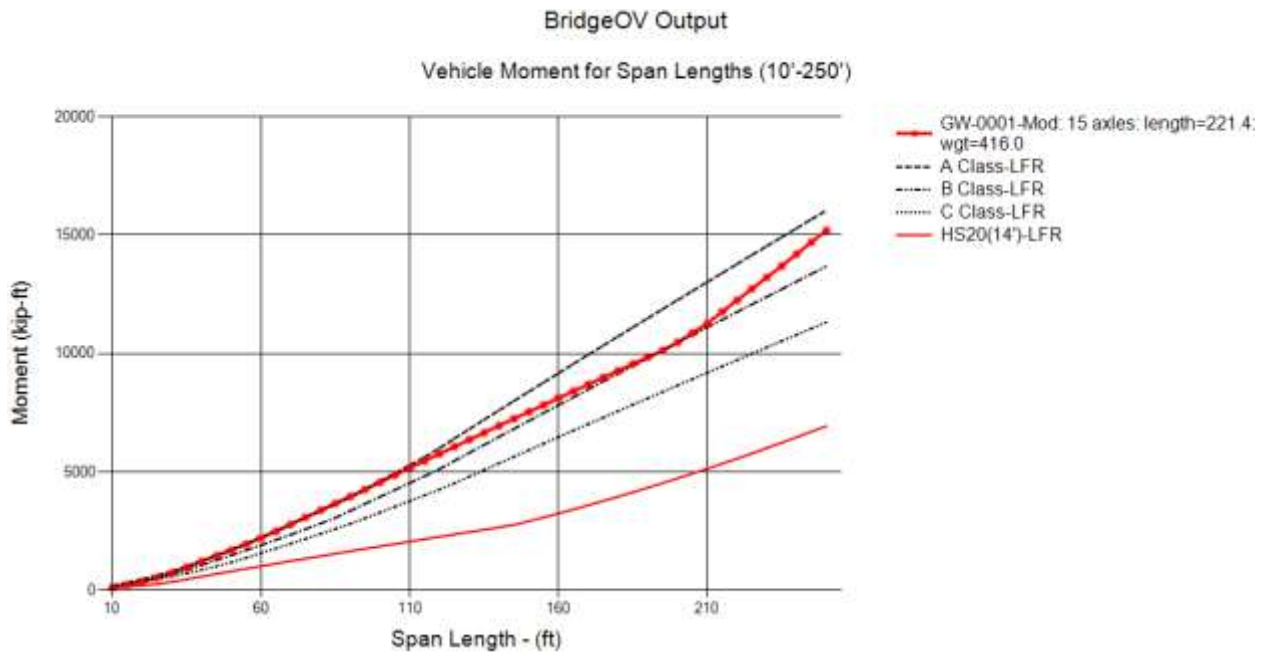


Figure 51. BridgeOV moment plot for revised permit vehicle

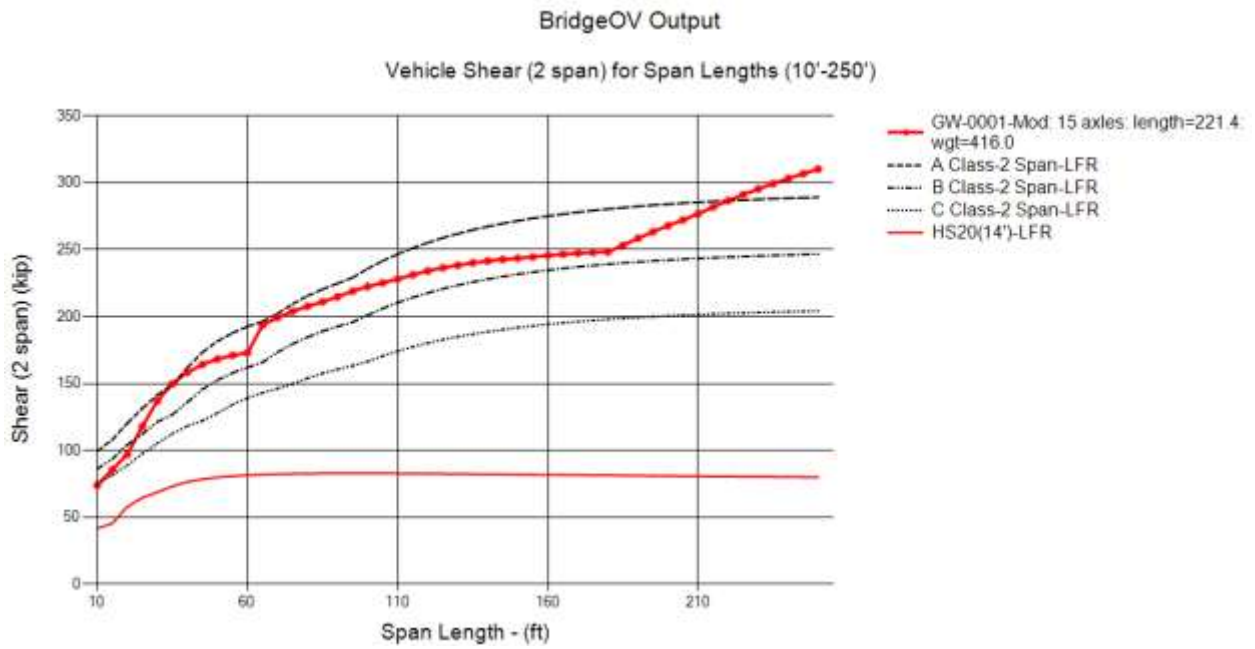


Figure 52. BridgeOV shear plot for revised permit vehicle

5.1.7 Review of Continuous Span Structures

MDOT provided the researchers with a set of 30 Virtis bridges with multiple continuous spans. This set was used to determine if the revised BridgeOV, that only checks moment for simple spans and shear for simple spans and 2-equal spans, provides conservative results. Upon review of the structures, it was determined that two of the bridges (41141064000R020 and 49149025000S050) contained only simple span structures and were not used for this analysis. The remaining structures were run in Virtis using LFR and with distribution factors of 2.0 so that the results could be compared against the moments and shears produced by the revised bridge OV program.

To compare the results, the Virtis maximum live load moments (positive and negative) were saved from an envelope of all 20 Class A Michigan overload vehicles. The 20 vehicles were also run in BridgeOV and the results saved. For BridgeOV, the maximum span length of the structure was used as the key for determining the moment or shear. Initially the BridgeOV values were taken at 1' span increments (rounded up) based on the maximum span length for each structure. These values are represented in Table 16. In this table the BridgeOV / Virtis ratio is expected to be greater than 1.0 if the values are to be conservative. Using this method, bridges (BID) 26, 31, 34, 35, 36, 42, 50 and 55 fail the shear ratio with ratios ranging from 0.972 to 0.999. In addition, bridges (BID) 41 and 42 fail the moment ratio checks with ratios of 0.987 and 0.944 respectively (see Table 16).

The criteria was changed to use the maximum span length for the bridge rounded up to the next 10-ft increment and adding 10-ft on to the increment. For example if the maximum span length for the bridge is 54.0-ft (BID 28), the span length used for BridgeOV would be 60-ft + 10-ft or 70-ft. When the criteria was changed to this, all bridges for moment passed with the lowest ratio being 1.116. In addition, two BID 26 and 36 still have ratios slightly less than one (see Table 17).

It seem that the likely issue for these two bridges is that they are both relatively long span bridges with a shorter span next to the maximum length span. In the case of BID 26 the span lengths are (157-ft, 122-ft, 122-ft, and 122-ft) with the maximum negative shear of 281.9 kip being located at the support between the 157-ft and 122-ft span bridge (see Figure 53).

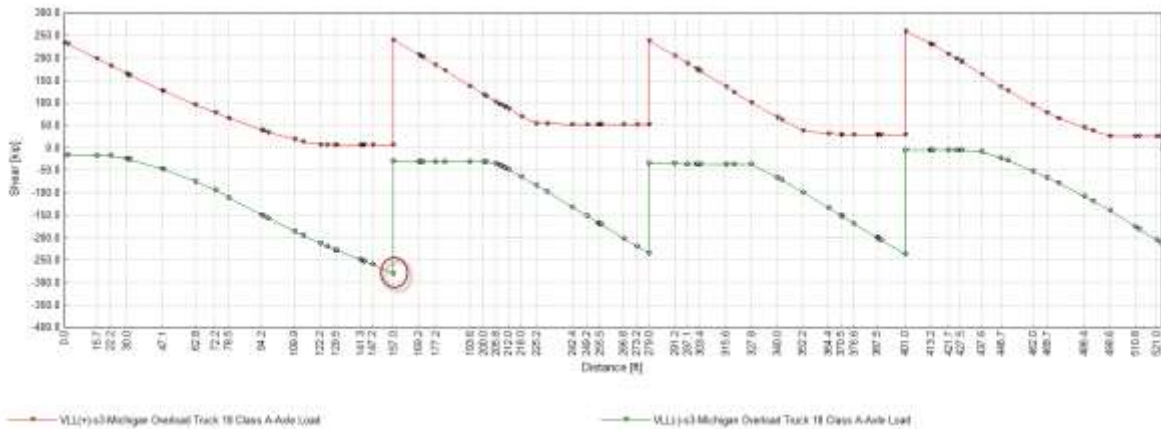


Figure 53. Plot of BID 26 shear in Virtis

The impact for the axles loaded in span 1 would be

$$Impact = \frac{50}{L + 125} = \frac{50}{157 + 125} = 0.177$$

While the impact for axles loaded in Span 2 would be higher because of the shorter span length

$$Impact = \frac{50}{L + 125} = \frac{50}{122 + 125} = 0.202$$

The BridgeOV calculation would use the impact for the longer span and thus use a reduced impact factor. Using an even larger span does increase the shear, but also reduces the impact factor.

One possibility would be to make the impact factor constant (e.g. 1.33) for the shear calculations in BridgeOV altogether although this will mean change in the allowable values as well.

Another possibility is to increase the maximum span length provided by the NBI data by a factor. Currently, in the revised version of the BridgeOV software, the factor has been set as a user input and defaults to 1.2, meaning that the maximum span length from the NBI data is multiplied by 1.2 and round up to the next highest 5-ft increment.

Example:

NBI span length = 69-ft

Maximum span length = 1.2 * 69 = 82.8-ft round up and use 85-ft as the maximum span length.

Table 16. Virtis /BridgeOV comparisons on 30 bridge MDOT sample using 'Max Span Length' to nearest 1'

BID	Bridge Id	Bridge Name	Number of Multi-Span Structures	Num Spans Struct	Max Span Length	Virtis**				BridgeOV			
						Max Positive Moment (kip-ft)	Max Negative Moment (kip-ft)	Max Pos Shear (kip)	Max Negative Shear (kip)	BridgeOV Moment (Simple)* (kip-ft)	Shear (Simple)* (kip)	BridgeOV 2 span* (kip)	Max Virtis Moment (kip-ft)
26	63163192000S010	I-96 EB, RAMP J OVER M-5/I-96/I	2	4	157.0	6897.0	4796.9	258.3	281.9	8940.3	253.0	274.0	6897
26	63163192000S010	I-96 EB, RAMP J OVER M-5/I-96/I	2	3	156.0	5100.8	4007.6	262.9	262.9	8862.2	252.6	274.0	5100.8
27	82182023000S270	M-10 NB OVER I-94	1	6	57.4	1510.6	1070.4	182.6	182.3	2098.3	175.8	189.7	1510.6
28	82182192000S040	OAKWOOD BLVD OVER M-39	1	2	54.0	1612.2	1312.9	183.7	183.7	1938.9	172.7	186.5	1612.2
29	41141064000R020	M-6 EB OVER NORFOLK SOUTHERN	0	1	0.0								
30	63163111000R020	I-75 BL NB OVER GTW RR	1	4	78.0	2678.9	830.6	202.5	200.5	3250.3	195.3	213.0	2678.9
31	19119033000S090	TAFT ROAD OVER US-127	1	2	105.4	3938.4	2927.5	241.7	241.7	4952.6	220.4	241.4	3938.4
32	11111016000B013	I-94 EB OVER ST. JOSEPH RIVER	1	8	84.0	3548.8	940.7	205.8	205.8	3582.7	201.4	219.4	3548.8
33	23123063000S130	DAVIS HWY OVER I-69	1	2	170.6	7942.1	4761.5	280.6	273.4	10105.8	257.7	278.1	7942.1
34	82182022000S430	M-39 SB RAMP L over I-94	1	3	30.0	654.4	634.5	141.7	141.7	807.9	133.1	141.3	654.4
35	49149025000S050	CHARLES MORAN RD OVER I-75 S	0	0	0.0								
36	38138101000S100	DETTMAN RD over I-94	1	2	167.8	7938.7	4342.1	281.6	262.9	9796.1	256.8	277.3	7938.7
37	50150062000S110	I-696 RAMP N TO W OVER I-94	1	4	109.1	5220.8	1330.9	240.3	237.4	5223.5	224.2	245.6	5220.8
38	63163191000S010	MEADOWBROOK RD OVER I-96	1	2	153.7	7605.5	3194.3	244.1	272.4	8705.8	251.8	272.9	7605.5
39	82182081000S061	Evergreen Rd NB Over M-153	1	2	119.5	5366.4	2022.5	248.0	227.2	6012.5	233.4	255.0	5366.4
40	41141131000S110	HALL ST OVER US-131 and CENTU	1	2	73.3	2666.2	993.0	183.2	202.5	2971.5	189.3	206.5	2666.2
41	50150061000S030	RYAN ST OVER I-696	1	2	87.8	3854.4	1017.0	209.6	219.4	3802.8	204.9	223.0	3854.4
42	50150061000S140	SHERWOOD AVE OVER I-696 & R	1	6	141.8	8222.1	2056.3	250.8	272.5	7762.6	246.6	268.0	8222.1
43	82182291000B020	I-275 NB OVER HURON R & METR	1	4	83.2	3237.5	980.0	217.4	198.4	3527.5	200.4	218.4	3237.5
44	63163191000S100	TEN MILE ROAD OVER I-96	1	5	121.8	5024.3	1596.9	258.5	252.0	6172.9	234.8	256.5	5024.3
45	19119043000S020	Clark road over I-69 & US-127	1	5	141.0	6323.8	2596.2	266.6	261.8	7683.6	246.1	267.6	6323.8
46	25125031000S110	MILLER ROAD OVER I-75	1	2	63.6	2170.5	890.7	176.3	195.4	2469.1	182.0	195.5	2170.5
47	58158151000S100	LAPLAISANCE RD over I-75	1	4	112.3	2315.0	3664.8	239.9	228.0	5425.8	226.9	248.4	3664.8
48	25125132000S230	I-475 OVER STEVER - BROADWAY	2	7	78.6	2779	750.4	208.1	205.3	3305.9	196.4	214.2	2779
48	25125132000S230	I-475 OVER STEVER - BROADWAY	2	7	78.6	2779	750.4	208.1	205.3	3305.9	196.4	214.2	2779
49	50150111000S274	WB I-94 OVER CROCKER ROAD	1	3	100.4	3922.3	1018.2	225.3	225.3	4612.3	215.0	235.6	3922.3
50	82182022000S480	I-94 EB over M-39	3	4	31.3	677.9	667.8	143.7	143.7	846.3	139.7	142.9	677.9
50	82182022000S480	I-94 EB over M-39	3	4	30.0	654.4	634.5	141.7	141.7	807.9	139.7	141.3	654.4
50	82182022000S480	I-94 EB over M-39	3	4	35.0	812.6	773.9	148.8	140.6	1022.6	139.7	148.8	812.6
51	82182022000S420	I-94 EB RMP Over PELHAM RMP	2	4	30.5	660.7	650.2	142.6	142.6	846.3	134.6	142.9	660.7
51	82182022000S420	I-94 EB RMP Over PELHAM RMP	2	4	28.0	600.3	589.2	137.5	138.2	735.2	134.6	137.8	600.3
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	74.5	2461.2	2075	208	205.2	3027.3	191.8	209.2	2461.2
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	73.2	2397.5	2099.2	202.3	204.9	2971.5	191.8	206.5	2397.5
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	74.2	2431.1	2089.5	206.3	205.8	3027.3	191.8	207.9	2431.1
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	71.3	2292.5	2112.9	201.3	202.8	2859.7	191.8	203.6	2292.5
53	82182191000S240	I-75 RAMP C NB OVER TOLEDO D	1	5	104.5	4164.2	2612.5	223.2	234.9	4952.6	220.4	241.4	4164.2
54	41141027000B020	M-21 OVER GRAND RIVER	1	7	116.0	3279.4	3160.4	238	238	5695.5	230.3	251.9	3279.4
55	82182112000S348	M-102 Over M-10 & Ramps	3	5	128.5	6643.9	2285.1	252.4	239.5	6731.8	239.4	261.1	6643.9
55	82182112000S348	M-102 Over M-10 & Ramps	3	5	212.5	8895.8	4856.6	286.4	286.4	13250.8	267.3	285.5	8895.8
55	82182112000S348	M-102 Over M-10 & Ramps	3	7	142.0	6797	2349.6	256.3	260.6	7762.6	246.6	268.0	6797

* BridgeOV values taken at the nearest 1' increment

** Virtis values using a 2.0 DF with LFD impact applied

Table 17. Virtis /BridgeOV comparisons on 30 bridge MDOT sample using 'Max Span Length' rounded up to nearest 10' + 10'

BID	Bridge Id	Bridge Name	Number of Multi-Span Structures	Num Spans Struct	Max Span Length	Virtis**				BridgeOV Moment (Simple)* (kip-ft)	BridgeOV Shear * (kip)	BridgeOV 2 span Shear * (kip)	Max Virtis Moment (kip-ft)	Max Virtis Shear (kip)	Max BridgeOV Moment (kip-ft)	Max BridgeOV Shear (kip)	Ratio BridgeOV / Virtis Moment	Ratio BridgeOV/ Virtis Shear
						Max Positive Moment (kip-ft)	Max Negative Moment (kip-ft)	Max Pos Shear (kip)	Max Negative Shear (kip)									
26	63163192000S010	I-96 EB, RAMP J OVER M-5/I-96/I	2	4	157.0	6897.0	4796.9	258.3	281.9	9951.0	257.4	277.8	6897	281.9	9951.0	277.8	1.443	0.985
26	63163192000S010	I-96 EB, RAMP J OVER M-5/I-96/I	2	3	156.0	5100.8	4007.6	262.9	262.9	9951.0	257.4	277.8	5100.8	262.9	9951.0	277.8	1.951	1.057
27	82182023000S270	M-10 NB OVER I-94	1	6	57.4	1510.6	1070.4	182.6	182.3	2803.6	185.6	202.0	1510.6	182.6	2803.6	202.0	1.856	1.106
28	82182192000S040	OAKWOOD BLVD OVER M-39	1	2	54.0	1612.2	1312.9	183.7	183.7	2803.6	185.6	202.0	1612.2	183.7	2803.6	202.0	1.739	1.100
29	41141064000R020	M-6 EB OVER NORFOLK SOUTHERN	0	1	0.0													
30	63163111000R020	I-75 BL NB OVER GTW RR	1	4	78.0	2678.9	830.6	202.5	200.5	3926.6	206.5	224.6	2678.9	202.5	3926.6	224.6	1.466	1.109
31	19119033000S090	TAFT ROAD OVER US-127	1	2	105.4	3938.4	2927.5	241.7	241.7	6012.5	233.4	255.0	3938.4	241.7	6012.5	255.0	1.527	1.055
32	11111016000B013	I-94 EB OVER ST. JOSEPH RIVER	1	8	84.0	3548.8	940.7	205.8	205.8	4612.3	215.0	235.6	3548.8	205.8	4612.3	235.6	1.300	1.145
33	23123063000S130	DAVIS HWY OVER I-69	1	2	170.6	7942.1	4761.5	280.6	273.4	11494.5	262.8	282.2	7942.1	280.6	11494.5	282.2	1.447	1.006
34	82182022000S430	M-39 SB RAMP L over I-94	1	3	30.0	654.4	634.5	141.7	141.7	1734.3	167.8	141.3	654.4	141.7	1734.3	167.8	2.650	1.184
35	49149025000S050	CHARLES MORAN RD OVER I-75 S	0	0	0.0													
36	38138101000S100	DETTMAN RD over I-94	1	2	167.8	7938.7	4342.1	281.6	262.9	10724.6	260.3	280.2	7938.7	281.6	10724.6	280.2	1.351	0.995
37	50150062000S110	I-696 RAMP N TO W OVER I-94	1	4	109.1	5220.8	1330.9	240.3	237.4	6012.5	233.4	255.0	5220.8	240.3	6012.5	255.0	1.152	1.061
38	63163191000S010	MEADOWBROOK RD OVER I-96	1	2	153.7	7605.5	3194.3	244.1	272.4	9951.0	257.4	277.8	7605.5	272.4	9951.0	277.8	1.308	1.020
39	82182081000S061	Evergreen Rd NB Over M-153	1	2	119.5	5366.4	2022.5	248.0	227.2	6811.3	240.0	267.1	5366.4	248	6811.3	267.1	1.269	1.077
40	41141131000S110	HALL ST OVER US-131 and CENTU	1	2	73.3	2666.2	993.0	183.2	202.5	3926.6	206.5	224.6	2666.2	202.5	3926.6	224.6	1.473	1.109
41	50150061000S030	RYAN ST OVER I-696	1	2	87.8	3854.4	1017.0	209.6	219.4	4612.3	204.9	235.6	3854.4	219.4	4612.3	235.6	1.197	1.074
42	50150061000S140	SHERWOOD AVE OVER I-696 & R	1	6	141.8	8222.1	2056.3	250.8	272.5	9174.3	254.1	274.9	8222.1	272.5	9174.3	274.9	1.116	1.009
43	82182291000B020	I-275 NB OVER HURON R & METR	1	4	83.2	3237.5	980.0	217.4	198.4	4612.3	215.0	235.6	3237.5	217.4	4612.3	235.6	1.425	1.084
44	63163191000S100	TEN MILE ROAD OVER I-96	1	5	121.8	5024.3	1596.9	258.5	252.0	7604.5	245.6	267.1	5024.3	258.5	7604.5	267.1	1.514	1.033
45	19119043000S020	Clark road over I-69 & US-127	1	5	141.0	6323.8	2596.2	266.6	261.8	9174.3	254.1	274.9	6323.8	266.6	9174.3	274.9	1.451	1.031
46	25125031000S110	MILLER ROAD OVER I-75	1	2	63.6	2170.5	890.7	176.3	195.4	3361.4	197.4	215.3	2170.5	195.4	3361.4	215.3	1.549	1.102
47	58158151000S100	LAPLAISANCE RD over I-75	1	4	112.3	2315.0	3664.8	239.9	228.0	6811.3	240.0	261.7	3664.8	239.9	6811.3	261.7	1.859	1.091
48	25125132000S230	I-475 OVER STEVER - BROADWAY	2	7	78.6	2779	750.4	208.1	205.3	3926.6	206.5	224.6	2779	208.1	3926.6	224.6	1.413	1.079
48	25125132000S230	I-475 OVER STEVER - BROADWAY	2	7	78.6	2779	750.4	208.1	205.3	3926.6	206.5	224.6	2779	208.1	3926.6	224.6	1.413	1.079
49	50150111000S274	WB I-94 OVER CROCKER ROAD	1	3	100.4	3922.3	1018.2	225.3	225.3	6012.5	233.4	255.0	3922.3	225.3	6012.5	255.0	1.533	1.132
50	82182022000S480	I-94 EB over M-39	3	4	31.3	677.9	667.8	143.7	143.7	1734.3	167.8	181.4	677.9	143.7	1734.3	181.4	2.558	1.262
50	82182022000S480	I-94 EB over M-39	3	4	30.0	654.4	634.5	141.7	141.7	1734.3	167.8	181.4	654.4	141.7	1734.3	181.4	2.650	1.280
50	82182022000S480	I-94 EB over M-39	3	4	35.0	812.6	773.9	148.8	140.6	1734.3	167.8	181.4	812.6	148.8	1734.3	181.4	2.134	1.219
51	82182022000S420	I-94 EB RMP Over PELHAM RMP	2	4	30.5	660.7	650.2	142.6	142.6	1734.3	167.8	181.4	660.7	142.6	1734.3	181.4	2.625	1.272
51	82182022000S420	I-94 EB RMP Over PELHAM RMP	2	4	28.0	600.3	589.2	137.5	138.2	1253.7	150.2	161.7	600.3	138.2	1253.7	161.7	2.088	1.170
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	74.5	2461.2	2075	208	205.2	3926.6	206.5	224.6	2461.2	208	3926.6	224.6	1.595	1.080
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	73.2	2397.5	2099.2	202.3	204.9	3926.6	206.5	224.6	2397.5	204.9	3926.6	224.6	1.638	1.096
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	74.2	2431.1	2089.5	206.3	205.8	3926.6	206.5	224.6	2431.1	206.3	3926.6	224.6	1.615	1.089
52	13113033000B010	I-194 OVER KALAMAZOO RIVER	4	2	71.3	2292.5	2112.9	201.3	202.8	3926.6	206.5	224.6	2292.5	202.8	3926.6	224.6	1.713	1.108
53	82182191000S240	I-75 RAMP C NB OVER TOLEDO D	1	5	104.5	4164.2	2612.5	223.2	234.9	6012.5	233.4	255.0	4164.2	234.9	6012.5	255.0	1.444	1.086
54	41141027000B020	M-21 OVER GRAND RIVER	1	7	116.0	3279.4	3160.4	238	238	6811.3	240.0	261.7	3279.4	238	6811.3	261.7	2.077	1.100
55	82182112000S348	M-102 Over M-10 & Ramps	3	5	128.5	6643.9	2285.1	252.4	239.5	7604.5	245.6	267.1	6643.9	252.4	7604.5	267.1	1.145	1.058
55	82182112000S348	M-102 Over M-10 & Ramps	3	5	212.5	8895.8	4856.6	286.4	286.4	13250.8	267.3	288.3	8895.8	286.4	13250.8	288.3	1.490	1.007
55	82182112000S348	M-102 Over M-10 & Ramps	3	7	142.0	6797	2349.6	256.3	260.6	7762.6	246.6	274.9	6797	260.6	7762.6	274.9	1.142	1.055

* BridgeOV values taken at the next highest 10' + 10' (e.g. 141' would be taken at the 160' location)

** Virtis values using a 2.0 DF with LFD impact applied

5.1.8 BridgeOV – LFR vs. LRFR

A review of the effect of the BridgeOV results based on LFR and the Michigan implementation of LRFR was performed to determine the effect of varying live load factors as described in the Curtis, Till, Michigan Research Report “*Recommendations for Michigan Specific Load and Resistance Factor Design Loads and Load and Resistance Factor Rating Procedures*”.

As per the recommendation from MDOT, equation 18 from that report was implemented in BridgeOV along with a new input item that specifies if the BridgeOV run is and LRFR or LFR run. The BridgeOV input file is described in Section 10.3.2 of this report. Equation 18 from the Curtis, Till report is shown below

$$\gamma_{equiv} = 1.8 * \frac{\left(P + \left(\frac{g_m}{g_l} - 1\right)A_T\right)}{120} * \frac{72}{P} * \frac{g_l}{g_m} \quad \text{Equation 18 (Curtis, Till)}$$

For the purposes of implementing in BridgeOV, MDOT provided the following constants for the implementation of this equation.

- ADTT = 5000 which yields a value of A_T of 188.6 as per Table 18 (p. 18) of the report.
- $g_m / g_l = 2.0$
- P = gross weight of the vehicle

5.1.8.1 Three-Axle Vehicle – LFR vs. LRFR

An initial investigation was conducted by modifying a simple 3 axle vehicle by changing the axle loads. The vehicle used for the analysis is described in Figure 54. Vehicle TV1 is simply the HS-20 vehicle without the variable axle spacing. Vehicle TV2 is the vehicle with the same spacing but with the middle axle increased from 32 kips to 60 kips. Vehicle TV3 is has the same configuration as vehicle TV2 but with the third axle increased from 32 kips to 46 kip. Therefore each vehicle is progressively heavier in gross weight.

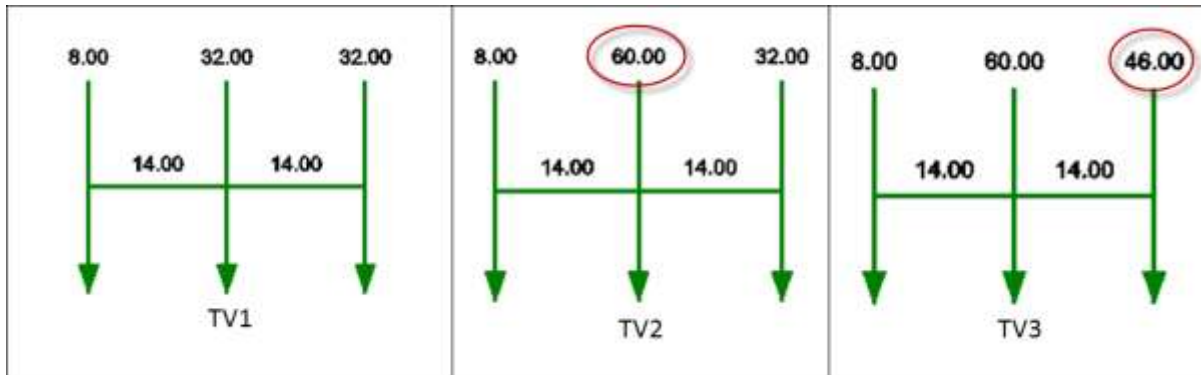


Figure 54. Modification of 3-axle vehicle used for the BridgeOV – LRFR load factor analysis

When Equation 18 from the Curtis, Till report is applied the factored axle loads are as shown in Table 18. Note that as the gross weight of the vehicle increases, the live load factor (γ_{equiv}) decreases. Note also that the gross factored weight of TV3 is 4.9% greater than the gross factored weight of TV2 whereas the unfactored gross weight of TV3 is 14% greater than that of the unfactored gross weight of TV2.

Table 18. Three vehicle test of MDOT LRFR live load factors

Vehicle	Axle Loads			Factored Axle Loads					
	Axle 1	Axle 2	Axle 3	Gross	LF γ_{equiv}	Axle 1	Axle 2	Axle 3	Gross/Factored
TV1	8	32	32	72	1.800*	14.40	57.60	57.60	140.8
TV2	8	60	32	100	1.558	12.47	93.51	49.87	155.8
TV3	8	60	46	114	1.433	11.47	86.00	65.93	163.4
*Maximum Value									

The changing of the axle load from vehicle TV2 to TV3 and the accompanying lowering of the load factor as the vehicle load increases, leads to some peculiar behavior for shorter span moment checks in BridgeOV.

The graph in Figure 55 shows the TV2 and TV3 moment plots in BridgeOV using the LRFR option where the load factor varies with the gross weight of the vehicle. It can be seen for longer spans in this figure that curve for TV2 (the lighter vehicle) is below the TV3 vehicle as expected.

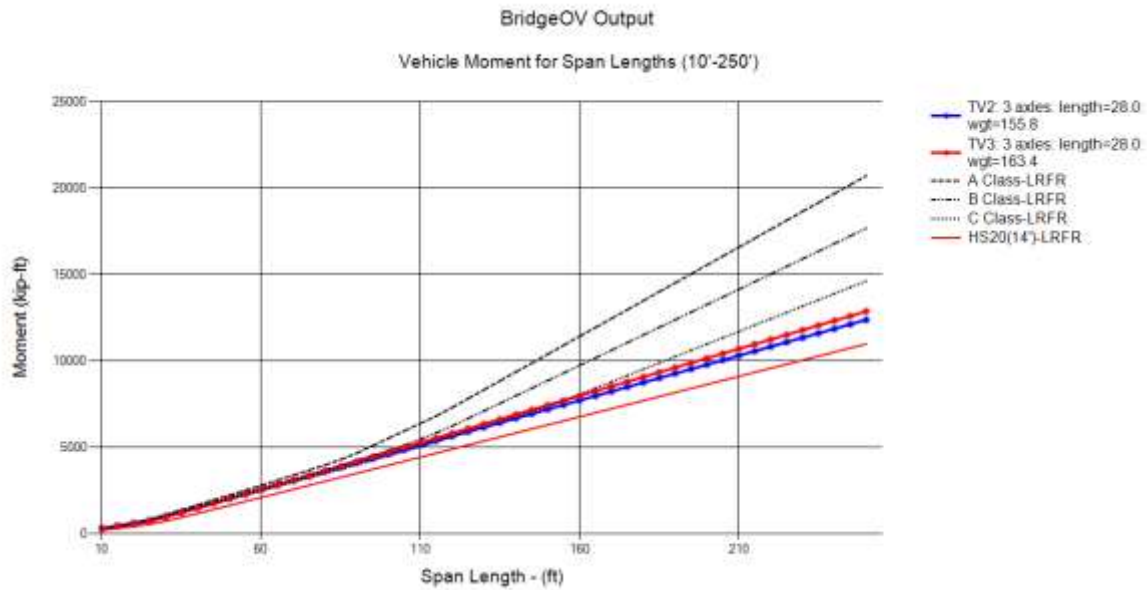


Figure 55. LRFR BridgeOV moment comparison of TV2 and TV3 from 10'-250'

Looking closer at the shorter span lengths in Figure 56, however reveals that the heavier TV3 vehicle moment falls below the lighter TV2 vehicle curve, thus showing that as the axle weight of the third axle is increased, the comparisons for the simple span moment are improved (or made smaller).

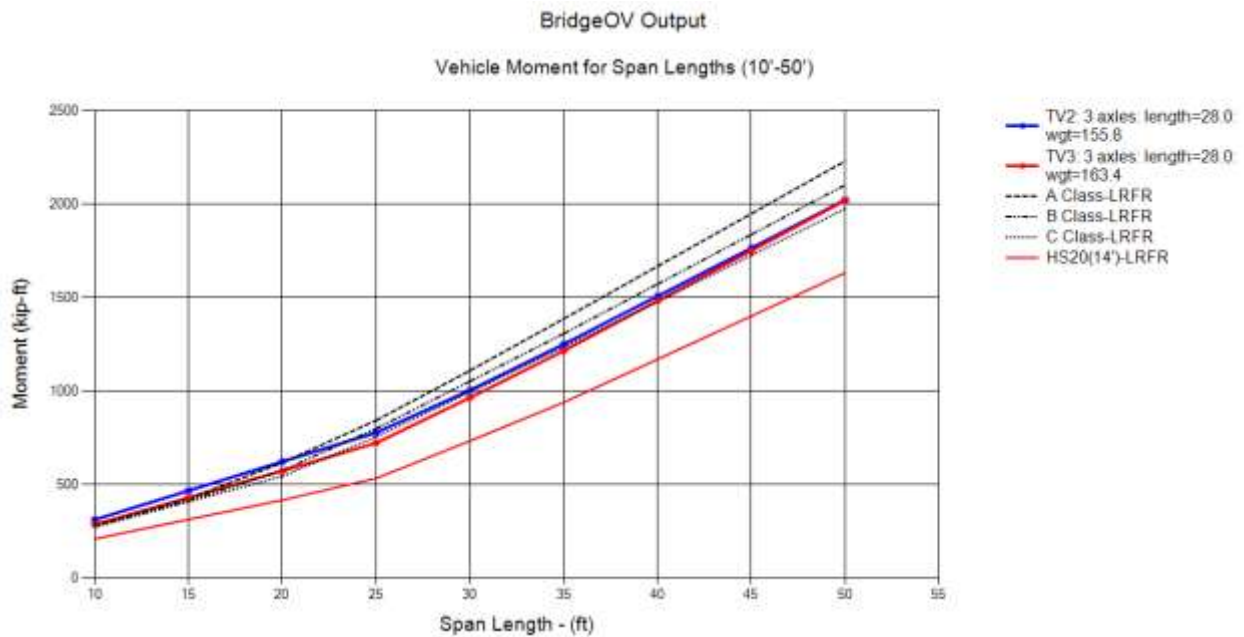


Figure 56. LRFR BridgeOV moment comparison of TV2 and TV3 from 10'-50'

Plotting the same moment curves using the LFR option yields different results as the lighter vehicle TV2 vehicle curve falls below the heavier TV3 vehicle curve (see Figure 57).

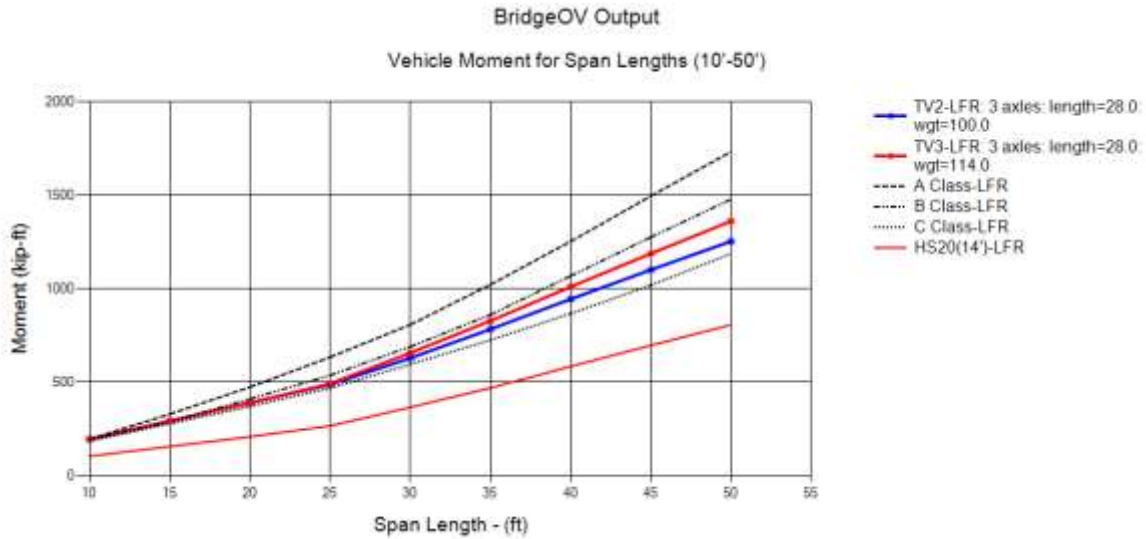


Figure 57. LFR BridgeOV moment comparison of TV2 and TV3 from 10'-50'

A summary of the load factors for each vehicle as well as the moments at various span lengths are presented in Table 19 along with the controlling Michigan overload vehicle information at each span location. Note that for the LRFR spans of 20' and 50' the heavier TV3 vehicle has a lower moment in each case than the lighter TV2 vehicle.

Table 19. Overall comparison of vehicles TV1, TV2, and TV3 for LFR and LRFR

Span Length	Controlling Vehicle	Moment values from BridgeOV								
		Michigan Overloads			TV1		TV2		TV3	
		Impact	LF	Moment	LF	Moment	LF	Moment	LF	Moment
LRFR										
20	MIOLT-07	1.33	1.278	615.8	1.800	383.0	1.558	621.8	1.433	571.9
50	MIOLT-06	1.33	1.348	2229.7	1.800	1503.0	1.558	2022.1	1.433	2019.5
100	MIOLT-15	1.33	1.100	5520.9	1.800	3648.1	1.558	4607.1	1.433	4724.2
200	MIOLT-18	1.33	1.100	15545.4	1.800	7952.7	1.558	9786.1	1.433	10151.5
LFR										
20	MIOLT-13	1.300	1.000	473.9	1.000	208.0	1.000	390.0	1.000	390.0
50	MIOLT-17	1.286	1.000	1734.3	1.000	807.2	1.000	1254.3	1.000	1362.0
100	MIOLT-15	1.222	1.000	4612.3	1.000	1862.5	1.000	2716.7	1.000	3028.8
200	MIOLT-18	1.154	1.000	12260.4	1.000	3833.0	1.000	5447.7	1.000	6144.3

Perhaps a more revealing plot of the vehicles TV2 and TV3 for short spans is shown in Figure 58. For spans 10-ft – 20-ft the plots of the moment ratios (vehicle to HS20-14' spacing) are parallel. Since the length of the vehicle is longer than the bridge for these cases, the heavier of the axles is governing for each (which is 60 kips, unfactored). Since the TV2 vehicle has a higher load factor, it is governing over the TV3 vehicle with the lower load factor. Even though the overall factored gross weight of TV3 is larger than that of TV2, the portion that can be placed on the structure is heavier for TV2. This demonstrates that for the same number of axles and the same axle spacing, increasing the axle loads can reduce the factored load effect in some cases.

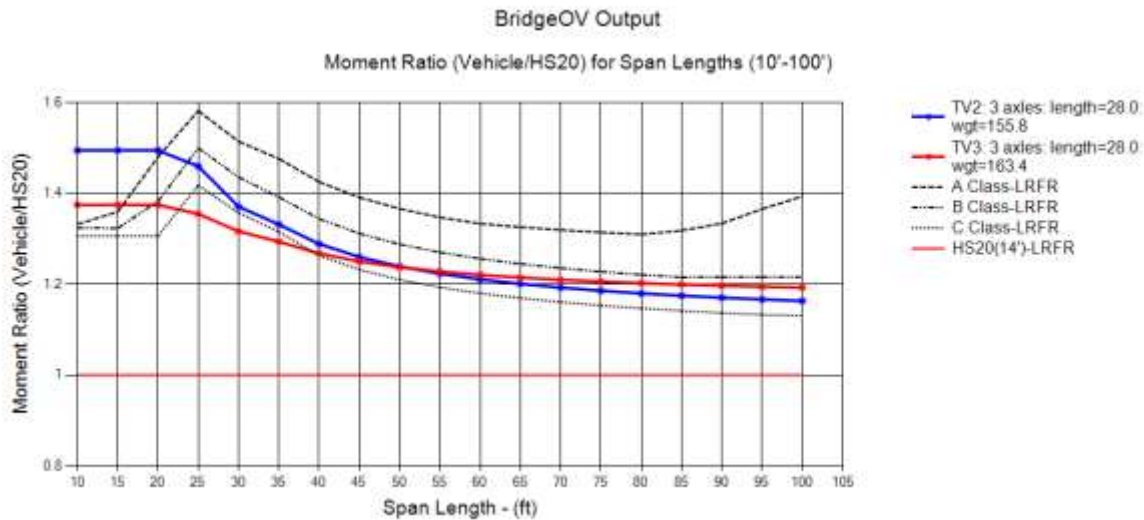


Figure 58. BridgeOV Moment ratio plot of LRFR vehicles TV2 and TV3

5.1.8.2 Review of the Permit Vehicles in LRFR

This section reviews the effects of running some the permit vehicles discussed in previous sections using the BridgeOV LRFR option. As with the vehicle analysis discussed in previous sections, gage spacing was not considered as the gage spacing was not available in the data provided by TPU. Also, girder distribution factors could not be considered since the results were only being reviewed in light of the changes being made to BridgeOV.

5- axle closely spaced 24 kip loads

In Section 5.1.4.6, a 5 axle vehicle with 24 kip loads spaced at 4' was reviewed using BridgeOV at the request of MDOT. The plot for the moment ratio is reproduced in Figure 59 (LFR) and Figure 60 (LRFR) below.

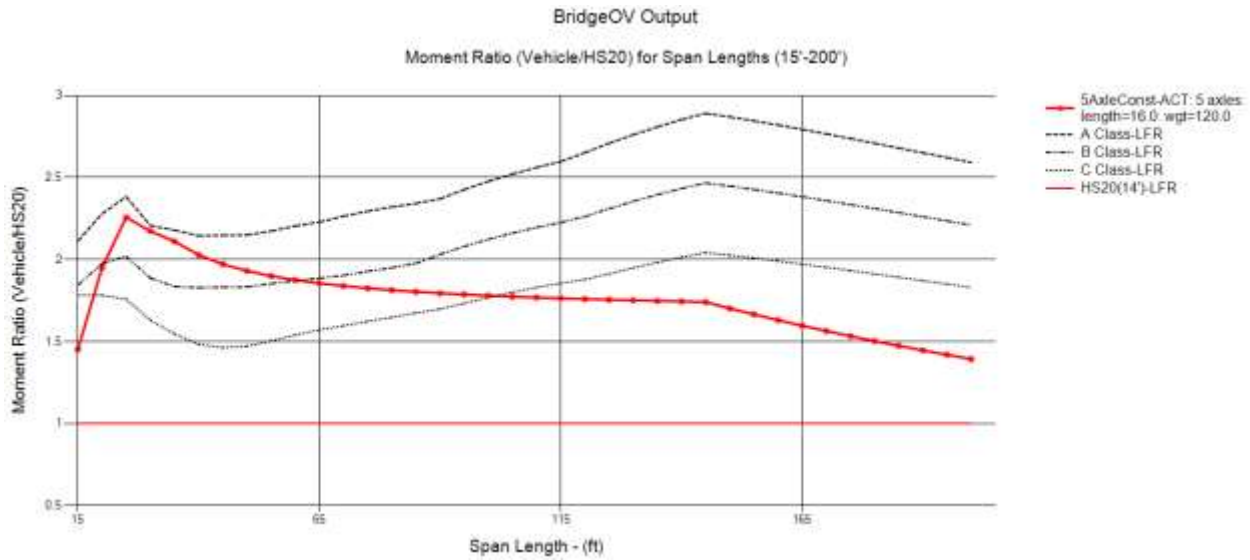


Figure 59. LFR BridgeOV moment plot -5-axle short vehicle, 24 kip axle loads, 4' spacings

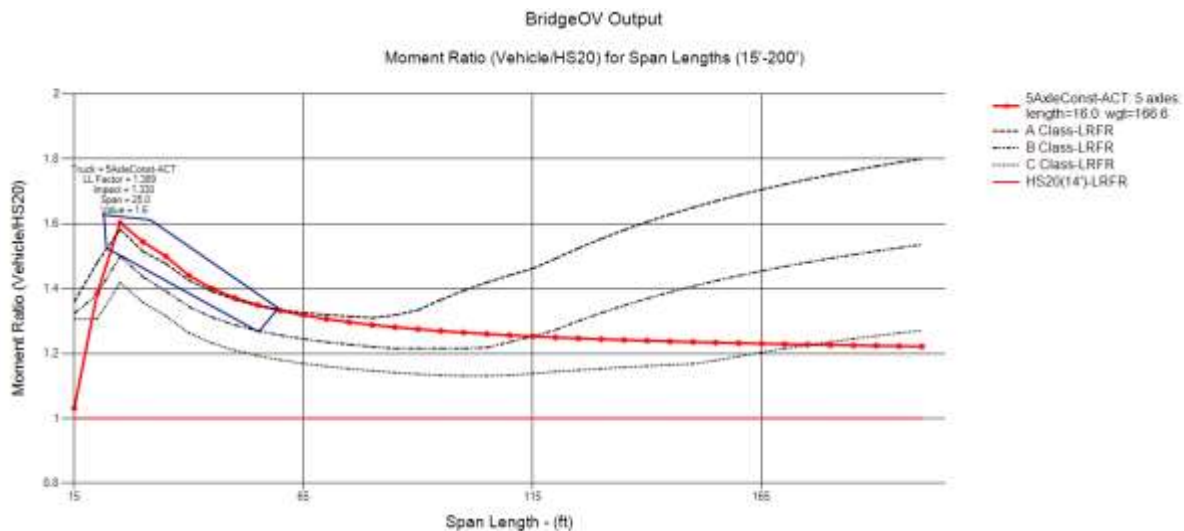


Figure 60. LRFR BridgeOV moment plot – 5-axle short vehicle, 24 kip axle loads, 4' spacings

Note that for LFR cases in the short span region, the vehicle curve approaches the Class A curve but does not exceed it. For LRFR, the Class A curve is exceeded for spans of length 25-ft through about 50-ft. The live load factor based on the Curtis/Till research for this vehicle is 1.389. The live load factors for the controlling overload vehicles are similar at these span lengths and are shown in Table 20. Also note in Table 20 that the controlling vehicles differ between LFR and LRFR. This appears to be due primarily to the difference in the load factor calculated for LRFR as per the Curtis/ Till Equation 18.

Table 20. Comparison of LRFR controlling overload live load factors with 5-axle construction vehicle

Span Length (ft)	Controlling Overload Vehicle (LFR)	Overload Vehicle Load Factor for LFR Controlling Vehicle*	Controlling Overload Vehicle (LRFR)	Overload Vehicle Load Factor (LRFR)	5-axle Construction Vehicle Load Factor
25	MIOLT-12	1.100	MIOLT-05	1.389	1.389
30	MIOLT-16	1.100	MIOLT-05	1.389	1.389
35	MIOLT-07	1.278	MIOLT-06	1.348	1.389
40	MIOLT-17	1.100	MIOLT-06	1.348	1.389
45	MIOLT-17	1.100	MIOLT-06	1.348	1.389
50	MIOLT-17	1.100	MIOLT-06	1.348	1.389

*This load factor is the calculated LRFR load factor based on Curtis/Till equation 18 but using the controlling overload vehicle for the LFR curve at the given span length.

Maximum Gross Weight

The maximum gross weight vehicles for LFR from the list of permit vehicles provided by MDOT were discussed in Section 5.1.4.5. The comparisons shown below (Figure 61) represent the BridgeOV moment ratio envelope for LFR and LRFR respectively. Note that for shorter spans, the enveloped LFR curve exceeds the allowable Class A curve while the LRFR curve is below or less than the Class A curve. It should be noted that because of the large weight of these vehicles, all of the live load factors are the minimum of 1.1. For shorter span lengths the load factors are higher; in the 1.348-1.389 range as shown in Table 20. This opens the possibility that these vehicles for LRFR would pass for short spans whereas in the past (LFR) they would have failed.

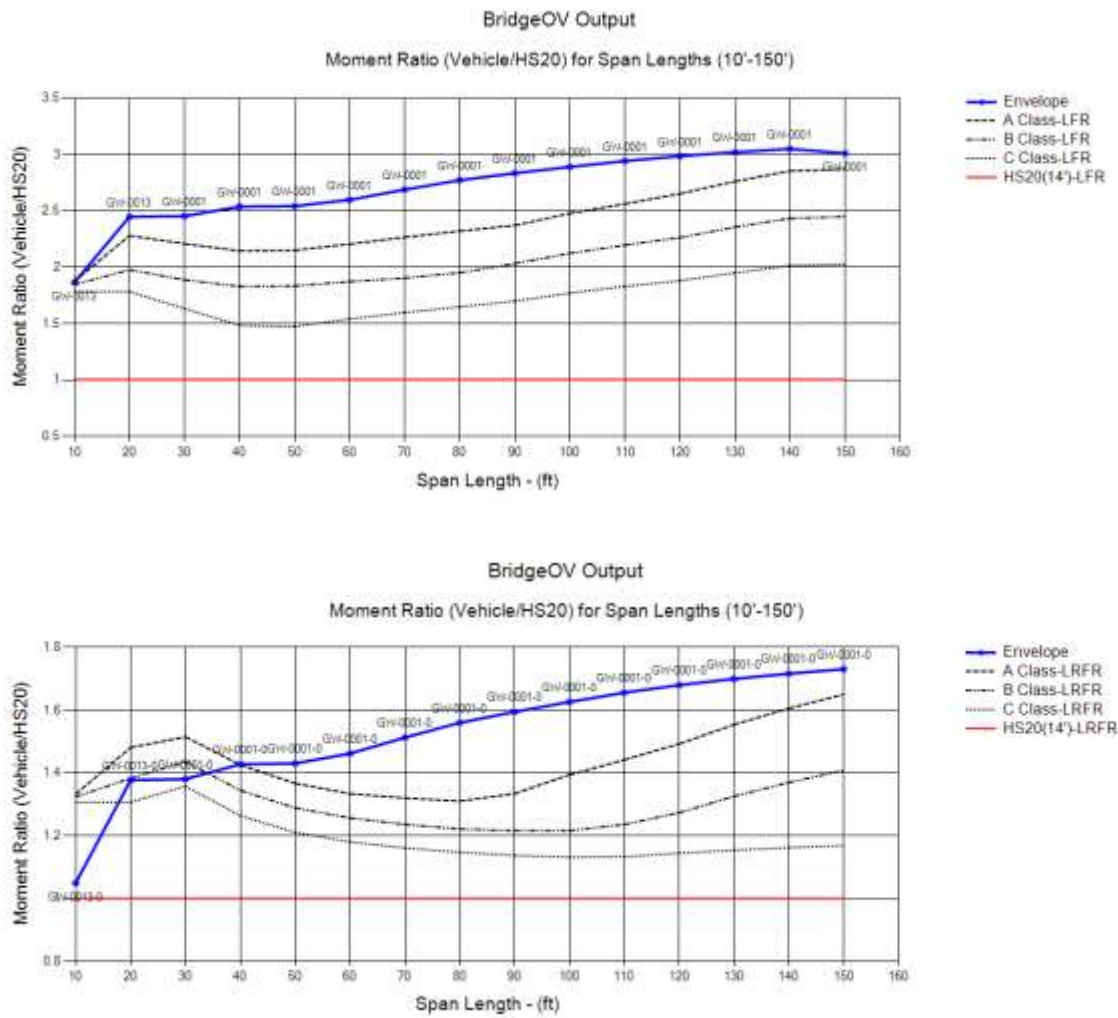


Figure 61. BridgeOV LFR/LRFR moment ratio envelope for maximum gross weight vehicles

Axle Concentrations

In Section 5.1.4, the permit vehicle list was reviewed by highest axle concentrations for 2, 3, 4, and 5 axles. The graphs shown in Figure 62 through Figure 65 show the vehicle envelope comparison for the moment ratios using the LFR and LRFR options in BridgeOV for each of the axle concentration. In general, while the curves appear close to one another for the longer span lengths, the shorter span lengths indicate the LRFR curves drop below the allowable Class A curve while the LFR envelope is above or exceeds the Class A curve.

Similar to the discussion of the 5-axle construction vehicle in the previous section, many of the governing vehicles for the short spans have low load factors (nearly all are 1.1) while the governing vehicles for the Class A curve have higher load factors. In addition, many of the governing vehicles have a total vehicle length such that the entire vehicle

does not fit on the bridge for shorter span lengths. A summary of the load factors for span lengths 25-ft – 50-ft is shown in Table 21.

Table 21. Calculated LRFR live load factors (Curtis/Till Equation 18)

Span Length (ft)	Controlling Overload Vehicle (LFR)	Total Length (ft)	Gross Weight /unfactored (kips)	LRFR Load Factor
2-axle concentration				
25	2AC-0015	70.3	208	1.100
30	2AC-0015	70.3	208	1.100
35	2AC-0016	221.4	480	1.100
40	2AC-0016	221.4	480	1.100
45	2AC-0016	221.4	480	1.100
50	2AC-0016	221.4	480	1.100
3-axle concentration				
25	3AC-0002	70.3	208	1.100
30	3AC-0002	70.3	208	1.100
35	3AC-0002	70.3	208	1.100
40	3AC-0002	70.3	208	1.100
45	3AC-0002	70.3	208	1.100
50	3AC-0005	29.9	150.2	1.218
4-axle concentration				
25	4AC-0001	70.3	208	1.100
30	4AC-0001	70.3	208	1.100
35	4AC-0011	221.4	480	1.100
40	4AC-0011	221.4	480	1.100
45	4AC-0011	221.4	480	1.100
50	4AC-0011	221.4	480	1.100
5-axle concentration				
25	5AC-0001	78.2	261	1.100
30	5AC-0001	78.2	261	1.100
35	5AC-0001	78.2	261	1.100
40	5AC-0001	78.2	261	1.100
45	5AC-0024	37.9	201	1.100
50	5AC-0024	37.9	201	1.100

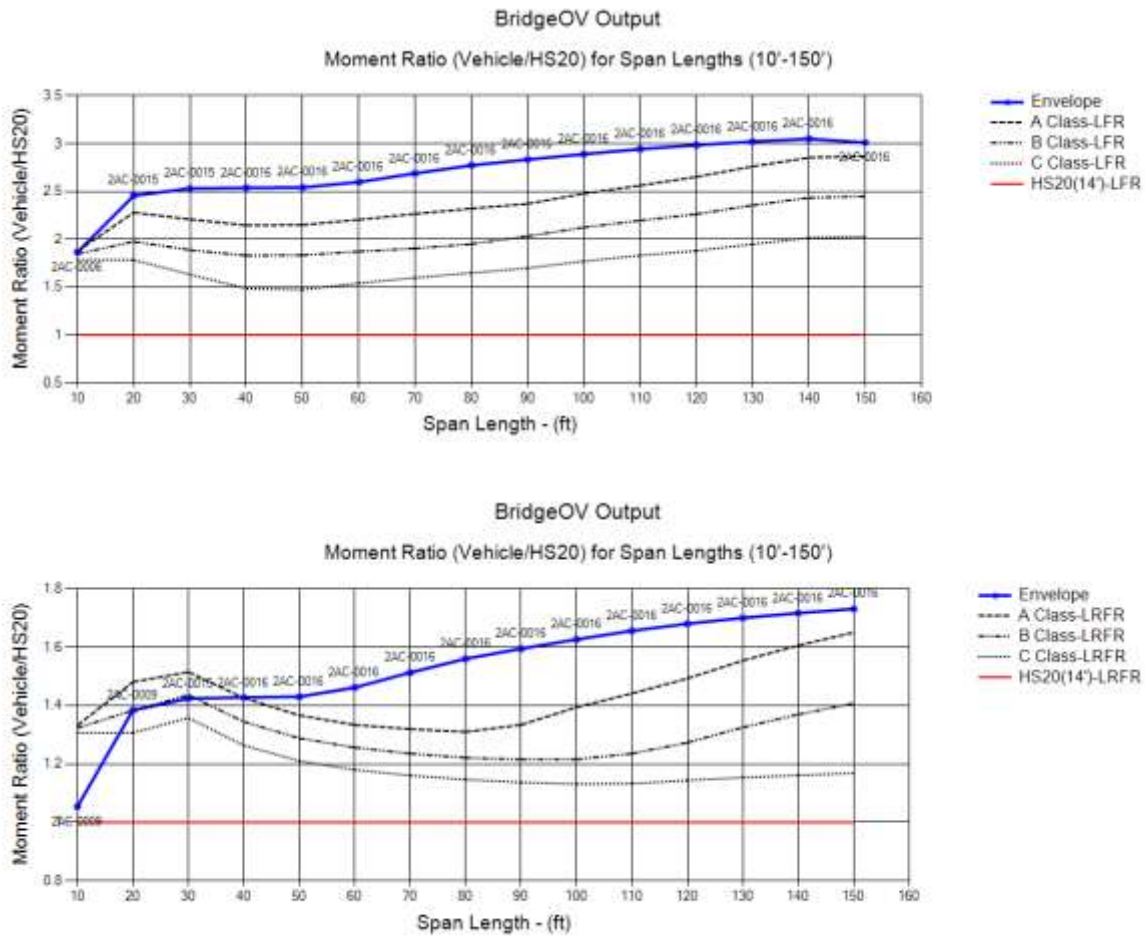


Figure 62. BridgeOV LFR/LRFR moment ratio envelope for 2-axle concentration vehicles

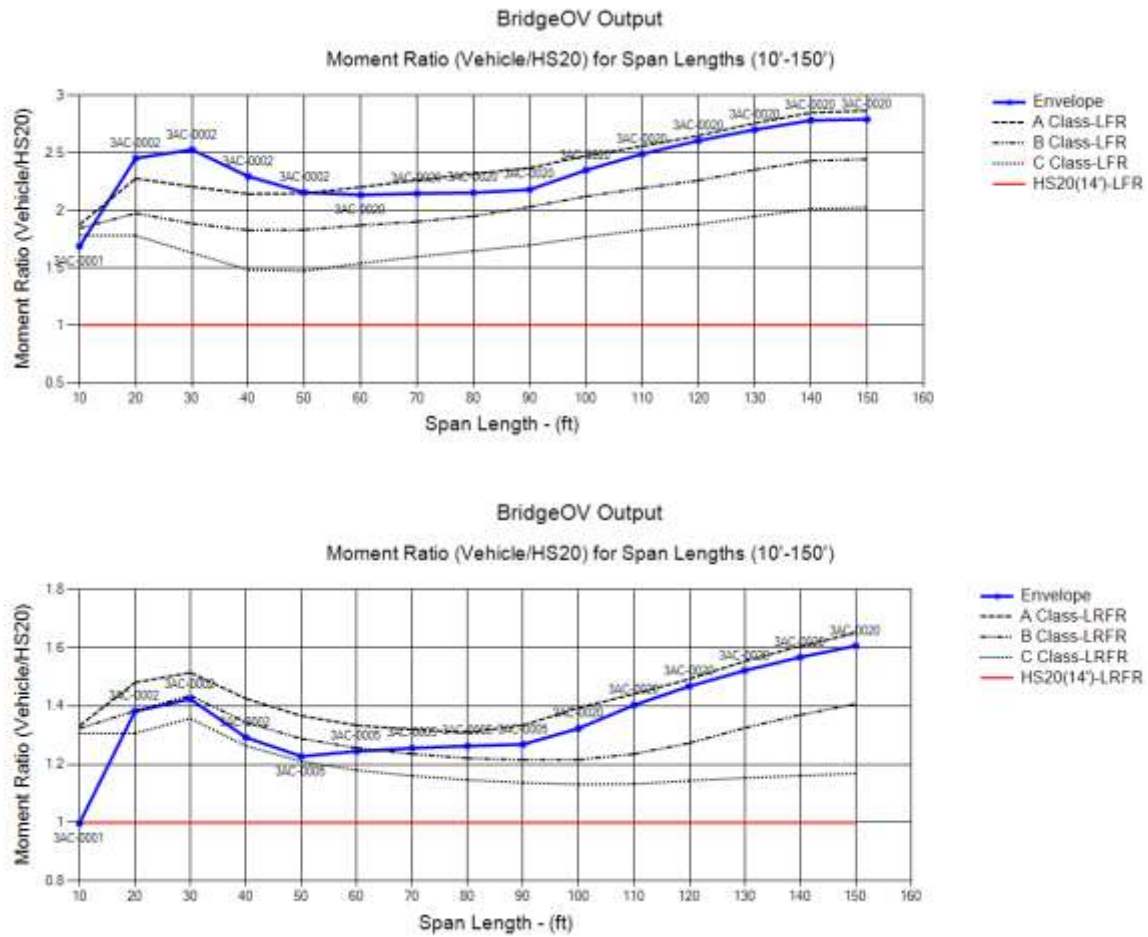


Figure 63. BridgeOV LFR/LRFR moment ratio envelope for 3-axle concentration vehicles

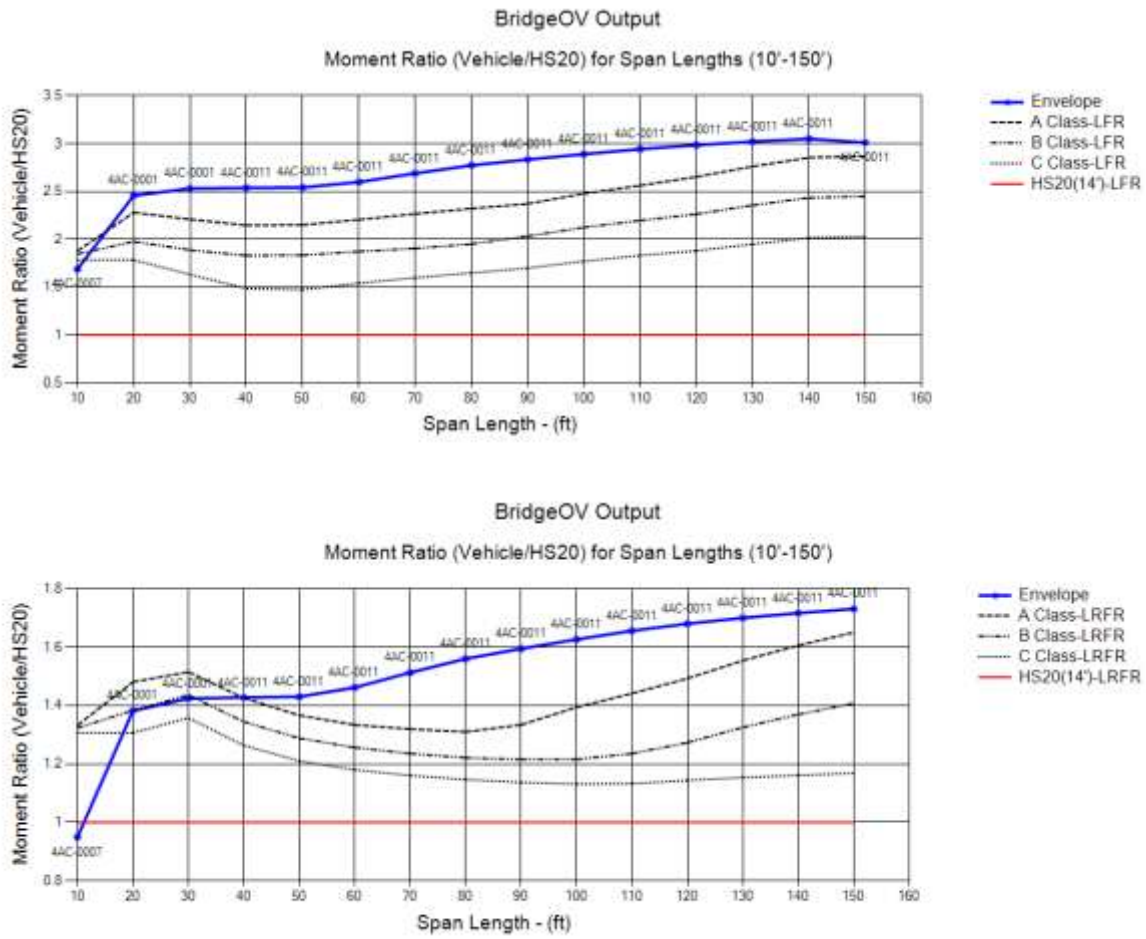


Figure 64. BridgeOV LFR/LRFR moment ratio envelope for 4-axle concentration vehicles

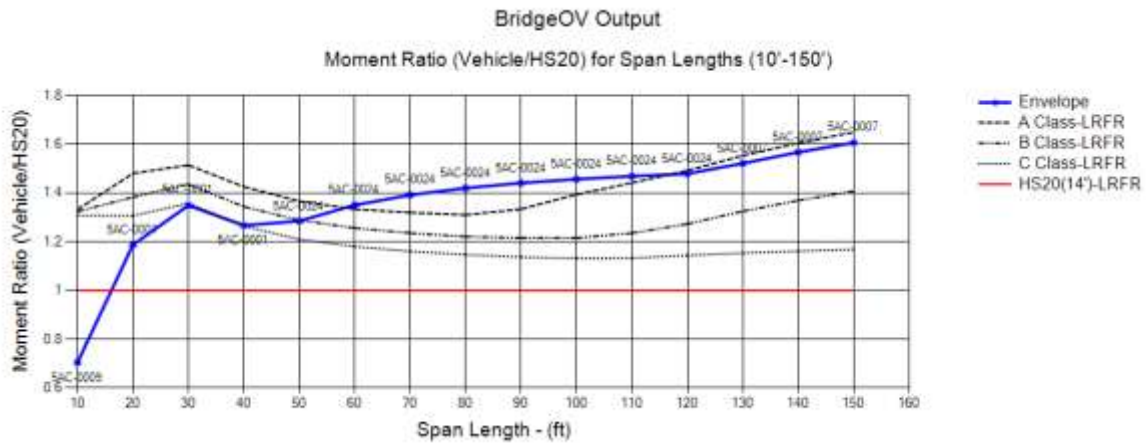
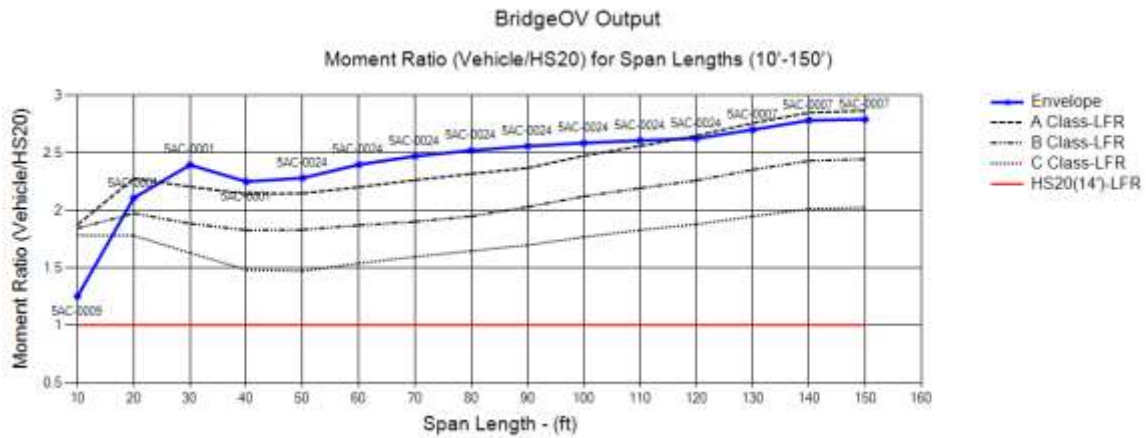


Figure 65. BridgeOV LFR/LRFR moment ratio envelope for 5-axle concentration vehicles

5.2 Discussion of Results

In general, the process of breaking down the permit vehicles using several different sorting methods provides a way to quickly review a larger set of vehicles while focusing on heavier loads and heavier load concentrations. The researchers believe that the methods outlined in this section can continue to be used in the future by MDOT using the software developed for this research project and using the data described in these sections as benchmarks.

5.3 Conclusions

The following table summarizes the conclusions for the various methods of analyzing the permit vehicles / overload vehicles described in the previous sections. When reviewing the permit vehicles, it should be noted that the gage information was not available in the data set. This could have an effect on the BridgeOV results observed if the gage distance results were known and included in the analysis. In general, the gage distance decreases the factor applied to the axles by $(1 / ((\text{gage} + 8) / 16))$. If the gage distance is the standard 8', the factor is equal to 1.0.

Method	Conclusions
Duplicate vehicles	The review of the duplicate vehicles provides a method for looking at the most commonly requested permit vehicles. While none of the vehicles that were most commonly occurring in the set exceeded the Class A allowable curve for moment or shear, several did exceed the Class B curve.
Vehicle anomalies	While reviewing the permit data set, it was noticed that several apparent anomalies existed in the data with either very small axle spacings or apparently small axle loads. As such, the PVA software includes some input parameters to detect such data.
Axle concentrations	Sorting the vehicles by axle concentrations (2, 3, 4, and 5 axles) permits the review of a large set of permit vehicles (in this case 16,000+) by logically sorting them into concentrations that will likely govern shear or moment. The axle concentration vehicles analyzed in this section demonstrate that these heavier loads can exceed the Class A curves and very often exceed Class B and C curves.
Maximum gross weight	This option is the easiest to sort by and captures the heaviest vehicles in the set regardless of the axle concentrations. This method is useful in combination with others and reveals vehicles that well exceed the Class A, B, and C curve.

Method	Conclusions
Five-axle construction vehicle	This vehicle does not exceed the Class A curve (although it comes close) but does violate the Class B and C curves for shorter span lengths. This may be a concern since this represents a possible construction vehicle that is subject only to extended permit requirements, which are not limited to Class A bridges.
Review of Michigan overload vehicles	<p>The 20 Michigan overload vehicles were reviewed with BridgeOV, and it was found that several of the vehicles (2, 3, 4, 6, 8, 11, 19 and 20) did not govern any of the points on the simple span moment, shear, or two-span shear Class A curve.</p> <p>Looking closer at sets of the vehicles, it was determined that several of the vehicles could possibly be eliminated, even if only for simple span analysis. The recommendations are provided in the next section.</p>
Review of NBI span length	Each bridge record in the NBI contains an item with the maximum span length for the structure. The researchers have concluded, based on our analysis that this value may be useful in determining the upper limit for the BridgeOV analysis. Some vehicles may pass the BridgeOV check for moment and shear on shorter spans but fail on longer spans. Thus, using the maximum span length to some degree as an upper limit would enable more short-span bridges to pass, particularly for longer length vehicles.
Review of continuous span structures	It was determined from the analysis of 28 continuous span structures provided by MDOT in Virtis and comparing them with the output of BridgeOV (which analyzes simple span for moment and shear and two-equal-span shear) that BridgeOV can be used if the maximum span length used for the BridgeOV run is set as the NBI maximum span length increased by at least a factor of 1.2 and rounded up to the nearest 5' increment.

Method	Conclusions
BridgeOV – LFR vs. LRFR	<p data-bbox="537 300 1430 583">LRFR capabilities were added to BridgeOV by incorporating Equation 18 of the Curtis/Till research provided by MDOT (see References section). Upon reviewing a simple 3-axle vehicle, it was noted that in shorter spans, the moment of a heavier vehicle could be less than a lighter vehicle even though the trucks were of the same length. This was attributable to the different load factors, which are a function of the weight, calculated for the vehicles.</p> <p data-bbox="537 611 1430 741">In addition, when reviewing the other vehicles analyzed in this section using the LRFR revision to BridgeOV, it was noted that for shorter span bridges, LRFR passes vehicles that would otherwise fail using the LFR option.</p>

5.4 Recommendations

The following table summarizes the researchers' recommendations based on the findings of the permit vehicle / overload vehicle analysis.

Method	Conclusions
Duplicate vehicles	<p>While none of the duplicate vehicles analyzed exceeded the Class A curve, several exceeded the Class B and C curves.</p> <p>We recommend that the PVA software be used periodically with data supplied by TPU (an Excel spreadsheet with a year's worth of permit vehicle data similar to that used for this study) using the data provided in this report for duplicate vehicles as a benchmark. This can be useful in developing trends in the types of vehicles being permitted.</p>
Vehicle anomalies	<p>We recommend that checks be placed somewhere in the MiTRIP software to detect anomalies in data such as too small and/or too large vehicle axle spacings and loads.</p> <p>We also recommend that the PVA software be used periodically with data supplied by TPU (an Excel spreadsheet with a year's worth of permit vehicle data similar to that used for this study) to determine if the anomaly checks added to MiTRIP are effective and, if not, adjusted.</p>
Axle concentrations	<p>Reviewing the axle concentrations revealed several vehicles that exceeded the Class A, B and C curves.</p> <p>We recommend that the PVA software be used periodically with data supplied by TPU (an Excel spreadsheet with a year's worth of permit vehicle data similar to that used for this study) using the data provided in this report for axle concentrations as a benchmark. This can be useful in developing trends in the types of vehicles being permitted.</p>
Maximum gross weight	<p>Reviewing the maximum gross weight vehicles revealed several vehicles that exceeded the Class A, B and C curves.</p> <p>We recommend that the PVA software be used periodically with data supplied by TPU (an Excel spreadsheet with a year's worth of permit vehicle data similar to that used for this study) using the data provided in this report for maximum gross weight vehicles as a benchmark. This can be useful in developing trends in the types of vehicles being permitted.</p>

Method	Conclusions
Five-axle construction vehicle	While this vehicle did not exceed the Class A mark, it was close. It did exceed the Class B and C curves for certain spans and should be viewed a bit closer, particularly if these vehicles can be used without permitting.
Review of Michigan overload vehicles	<p>While several of the Overload vehicles were shown not to govern, the BridgeOV analysis used to determine this was for simple span moment and shear and two-span shear only. Even so, it is recommended that vehicles 11, 19 and 20 could be removed from the set.</p> <p>As a minimum, when running Virtis structures for simple span, overload vehicles 2, 3, 4, 11, 19 and 20 could be removed as they appear to be covered by the other overload vehicles.</p>
Review of NBI span length	The researchers recommend using the NBI maximum span length with a factor of 1.2 when using BridgeOV in the MiTRIP software. This will allow some longer vehicles to pass for shorter span bridges.
Review of continuous span structures	Based on the review of the continuous span structures provided by MDOT, BridgeOV can be used with a maximum span length parameter of 1.2 within the MiTRIP software.
BridgeOV – LFR vs. LRFR	Based on the review of LRFR as implemented using the MDOT Curtis/Till research (see References section), and since The majority of the current bridge classifications used for MiTRIP would have been established using LFR, the researchers recommend using the LFR option in BridgeOV for the MiTRIP software.

6 Modifications to the BridgeOV Algorithm

Revisions to the original version of the BridgeOV algorithm were performed based on the recommendations made in the Interim Phase of this research. These revisions include:

- Updating the source code to C# .NET programming language
- Updating the moment tables
- Adding shear tables for simple spans
- Adding shear tables for 2-spans of equal length
- Providing graphical/ interactive features to the output

The following sections provide the methodology for the modifications/ enhancements as well as recommendations for implementation of the software.

6.1 Methodology

The BridgeOV algorithm was modified to include revised values for moments and for new values for shear. To develop the new curves for BridgeOV, the A, B and C class vehicles were used in an envelope fashion for span lengths from 10-ft – 250-ft in 1 foot increments. In the process, the values were checked/verified with Virtis and in the case of the moments, were compared to the original values provided in the BridgeOV table contained in the CLSABC2U.TXT file read in by the program (see Appendix F – Revised CLSABC2U.txt File). This file was provided with the original software by MDOT. The following sections describe the revisions.

For obtaining the shear and moment values produced by Virtis, span lengths for 20-ft – 200-ft were checked by using a simple span rolled beam using a set distribution factor of 2.0. Virtis runs for shear were also made for 2 equal span bridge lengths. The values for the shear and moment Virtis runs for these span lengths, along with comparisons to the new BridgeOV results and the original BridgeOV class A,B,C moment table are shown in Table 22, Table 23, and Table 24 at the end of this section.

6.1.1 Revisions to the Moment Table

To revise the moment tables, revisions were made to the BridgeOV software developed in the Interim Phase to produce an envelope of moments for a set of vehicles loaded into the software. To obtain the enveloped curve for Class A vehicles, all 20 Michigan overload vehicles were loaded into the BridgeOV software.

Once loaded, the files were plotted using the ‘Plot envelope of files’ option added to the interface (see Figure 66). Checking the box provides a plot and a table of points for the Class A vehicles (see Figure 67). Note, the moment values in the higher span ranges

for the envelope are slightly higher than the original BridgeOV tabular values. Also, no values are provided for above 200-ft in the previous version. The enveloped values were compared against the original BridgeOV values and with the Virtis software. The results compare favorably with Virtis values (see Table 22 at the end of this section). The original moment table, a text file (CLSABC2U.TXT), delivered by MDOT and used by the BridgeOV software, will be modified to include the newly calculated results.

The same comparison was made for Class B and C. There was a bit more separation for the moments in these categories as shown in Figure 68, Figure 69 and Table 22 (provided at the end of this section). The Class C results, in particular, were about 5-7% lower in the original program for the higher span lengths (see Table 22 at the end of this section). We are not sure why the original values were lower, but the researchers recommend the original BridgeOV table (CLSABC2U.TXT) be modified to include the newly calculated envelope of results.

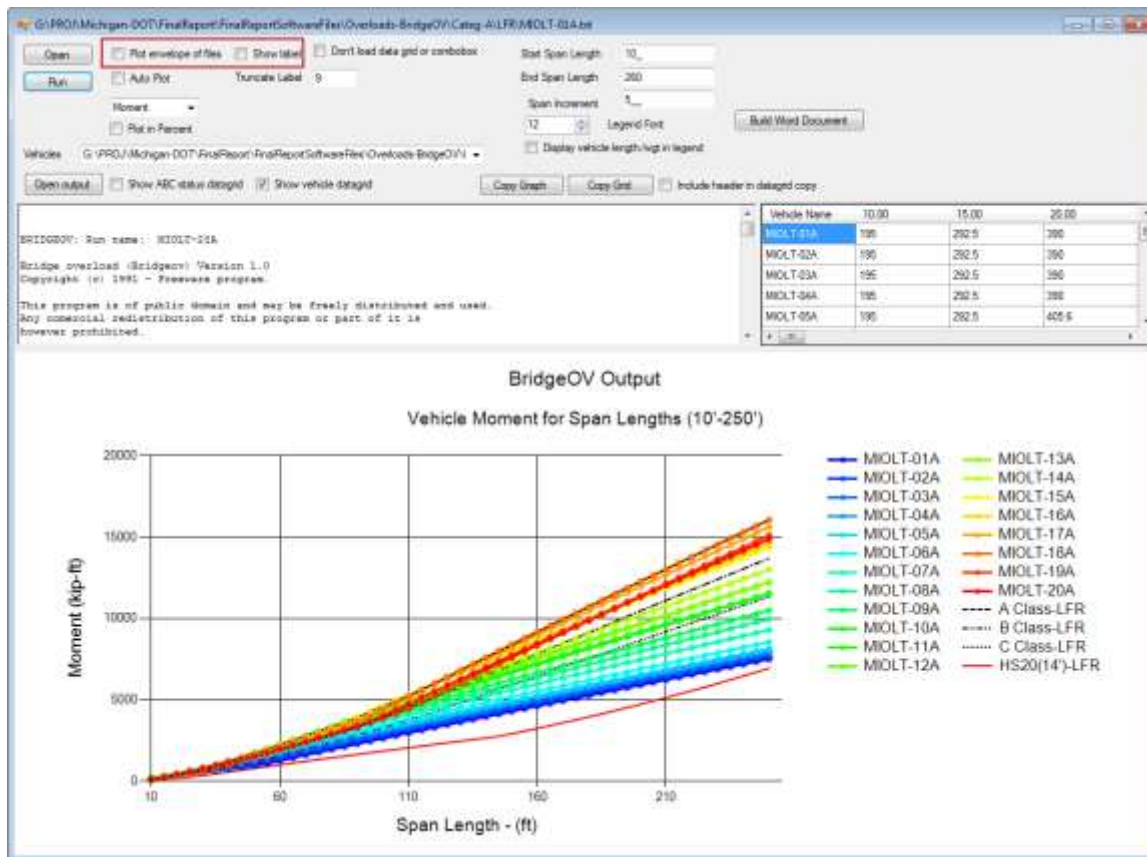


Figure 66. Plot envelope of files option in BridgeOV



Figure 67. Plot of Michigan Class A moment envelope with the existing BridgeOV Class A,B,C plots (10'-250')
NOTE: For this older version of BridgeOV, the Class A,B,C tables ended at 200'



Figure 68. Plot of Michigan Class B moment envelope with the existing BridgeOV Class A,B,C plots (10'-250')
NOTE: For this older version of BridgeOV, the Class A,B,C tables ended at 200'

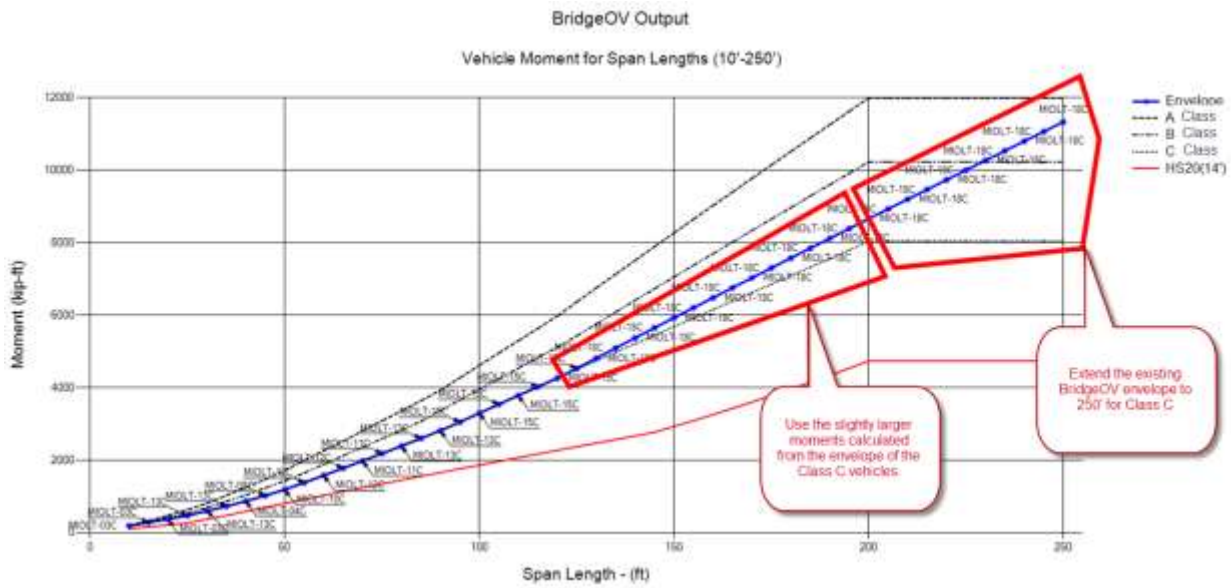


Figure 69. Plot of Michigan Class C moment envelope with the existing BridgeOV Class A,B,C plots (10'-250')
 NOTE: For this older version of BridgeOV, the Class A,B,C tables ended at 200'

Using the results of the enveloped moments for the Class A, B, and C vehicles, the CLSABC2U.TXT file was modified for new moments and to include span lengths up to 250-ft. The results of this modification are shown in Figure 70 with a sample vehicle.

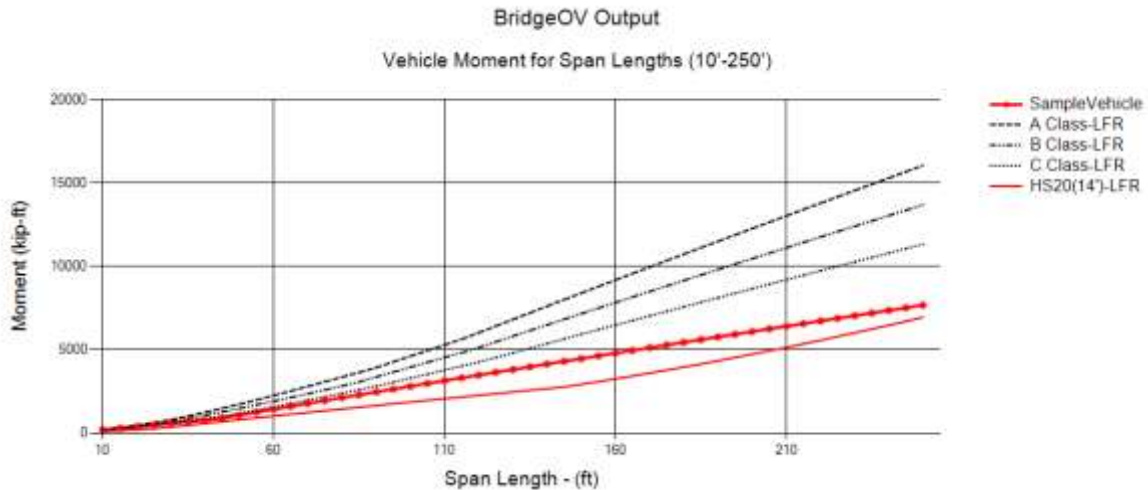


Figure 70. Plot showing new Class A,B, and C moments up to 250'

6.1.2 Addition of Shear Table

The original version of the BridgeOV software did not include a calculation for shear. Because shear can sometimes be the governing effect, especially for shorter spans, this calculation was added to the new version of BridgeOV, but the comparison tables for Class A, B, and C were not available in the CLSABC2U.TXT table. These values needed to be added. To do this, we needed to verify the calculation of the shear added to the BridgeOV software. Figure 71, Figure 72, and Figure 73 show the shear plots using the envelope feature of the new version of BridgeOV for Class A, B, and C respectively.

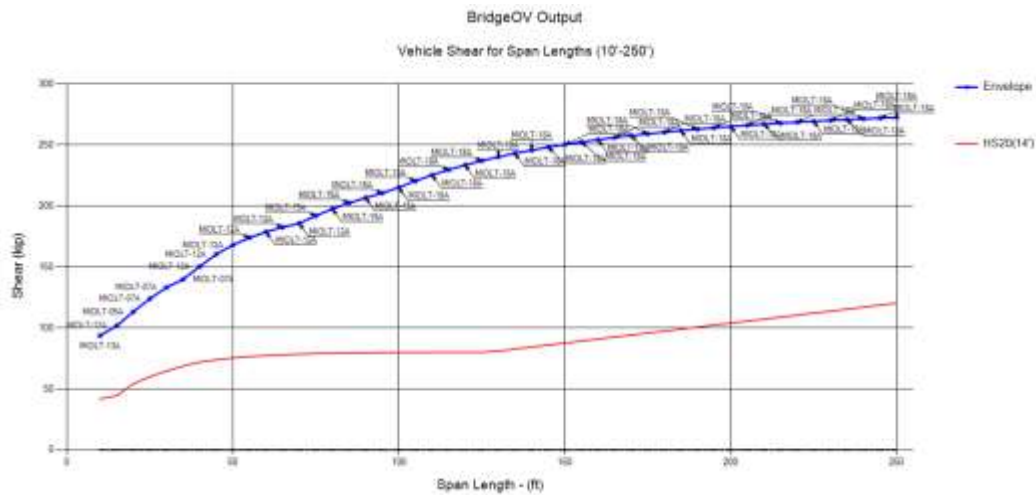


Figure 71. Plot of Michigan Class A shear envelope with the existing BridgeOV Class A,B,C plots (10'-250')
 NOTE: For this older version of BridgeOV, shear values were not available for Class A,B, or C

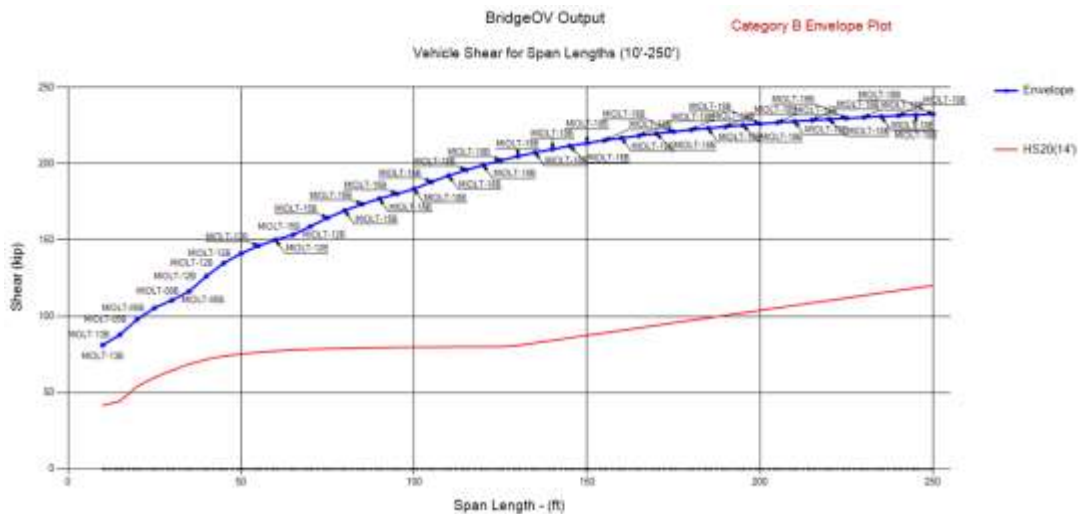


Figure 72. Plot of Michigan Class B shear envelope with the existing BridgeOV Class A,B,C plots (10'-250')
 NOTE: For this older version of BridgeOV, shear values were not available for Class A,B, or C

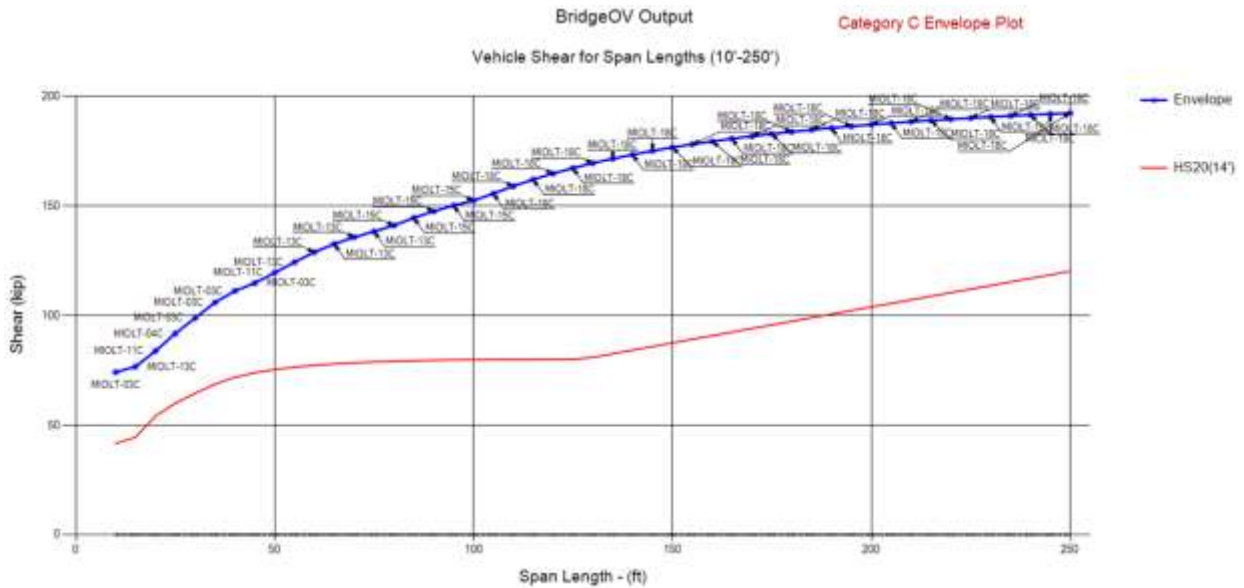


Figure 73. Plot of Michigan Class C shear envelope with the existing BridgeOV Class A,B,C plots (10'-250')
 NOTE: For this older version of BridgeOV, shear values were not available for Class A,B, or C

Since shear tables were not available in the original version of the BridgeOV software, comparisons were made at 10-ft intervals to the Virtis software. The results matched well with the Virtis software (within 0.1%) and are shown in Table 23 at the end of this section.

Since the shear results compared favorably (within 0.1%), the Class A, B, and C simple span shear results were added to the CLSABC2U.TXT file used by BridgeOV. The results of this addition are shown in Figure 74. The entire revised file CLSABC2U.TXT is shown in Appendix F of this document.

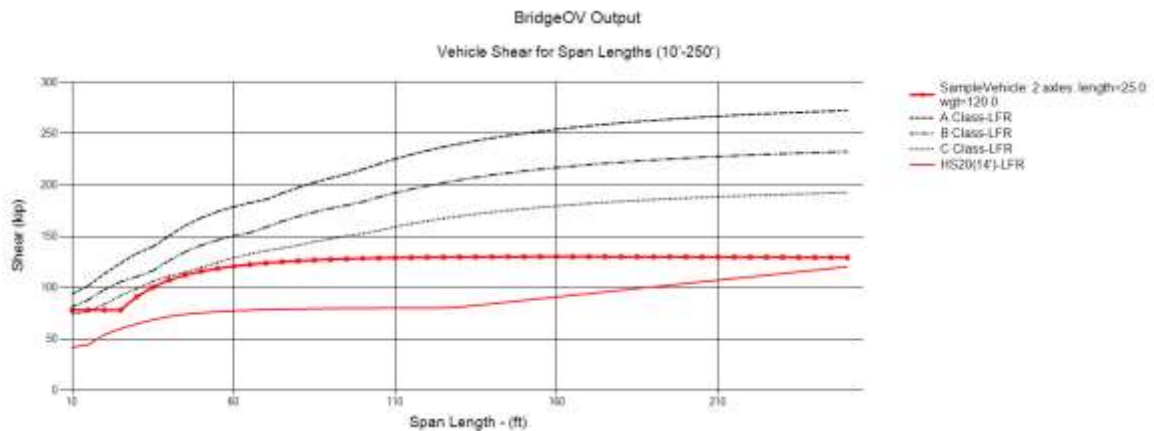


Figure 74. Plot showing the added A,B,C classes for simple span shear

6.1.3 Adding Shear for Two Equal Spans

For shear, the maximum effect could occur at an interior support. To account for this, BridgeOV was modified to include the shear calculation just to the left of the interior support of a structure with two equal span lengths. To perform this calculation, the AISC Beam Diagrams and Formulas (Ref: AISC Manual for Steel Construction) were used to compute the reaction 'R1' at the left most support and the shears were then computed just to the left of the interior support as the vehicle is stepped across the structure. This calculation was incorporated into BridgeOV. The maximum shear is then saved from all of the load steps.

The results of the BridgeOV addition for two equal spans were compared with results from a Virtis Line-girder run for spans from 20-ft – 200-ft in increments of 20-ft. The results compared favorably and are presented in Table 24 at the end of this section.

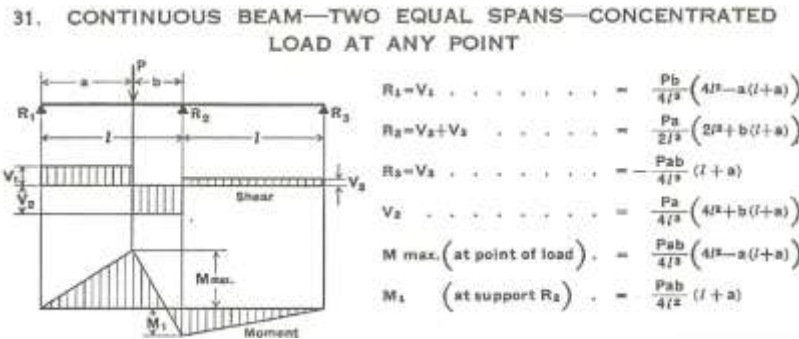


Figure 75. AISC beam diagrams and formulas for two equal spans

Since the two span shear results compared favorably, the Class A, B, and C, 2-span shear results were added to the CLSABC2U.TXT file used by BridgeOV. The results of this addition are shown in Figure 76. The entire revised file CLSABC2U.TXT is shown in Appendix F of this document.

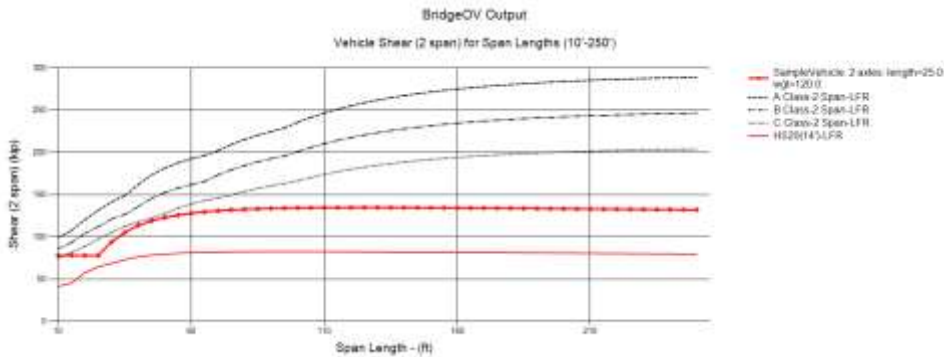


Figure 76. Plot showing the added A,B,C Classes for 2 equal spans shear

Table 22. Moment table comparing new BridgeOV overload values with existing BridgeOV table and Virtis

1	New BridgeOV Calculated Values (Overload Vehicles Envelope)						Values from Virtis Line Girder Analysis			Original BridgeOV Tables			Ratio of BridgeOV Tables with New Bridge OV Overload vehicle envelope			Ratio of new BridgeOV with Virtis calculated values		
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Span	Moment Envelope of Category A Vehicles	Controlling Vehicle - Category A	Moment Envelope of Category B Vehicles	Controlling Vehicle - Category B	Moment Envelope of Category C Vehicles	Controlling Vehicle - Category C	Virtis Moment Category A*	Virtis Moment Category B*	Virtis Moment Category C*	Category A Moment-BOV Table	Category B Moment-BOV Table	Category C Moment-BOV Table	Calculated /BOV Table Categ A	Calculated /BOV Table Categ B	Calculated /BOV Table Categ C	Calculated /Virtis Category A	Calculated /Virtis Category B	Calculated /Virtis Category C
15	329.5	MIOLT-13A	287.6	MIOLT-03B	277.9	MIOLT-03C				329.5	292.5	292.5	1.000	0.983	0.950			
20	473.9	MIOLT-13A	410.7	MIOLT-13B	370.5	MIOLT-03C	473.85	410.67	370.50	473.6	410	390	1.001	1.002	0.950	1.0000	1.0000	1.0000
25	634.2	MIOLT-12A	537.2	MIOLT-08B	467.8	MIOLT-13C				634	537.3	487.5	1.000	1.000	0.960			
30	807.9	MIOLT-16A	690.5	MIOLT-15B	596.7	MIOLT-13C	807.30	689.52	596.70	808.3	690.4	597	1.000	1.000	0.999	1.0008	1.0014	1.0000
35	1022.6	MIOLT-07A	861.2	MIOLT-06B	725.6	MIOLT-13C				1022.7	861.3	726	1.000	1.000	0.999			
40	1253.7	MIOLT-17A	1069.0	MIOLT-17B	867.1	MIOLT-04C	1253.56	1068.92	866.32	1245.2	1035.9	867.1	1.007	1.032	1.000	1.0001	1.0001	1.0009
45	1496.8	MIOLT-17A	1276.4	MIOLT-17B	1019.5	MIOLT-08C				1468.4	1232	1019.6	1.019	1.036	1.000			
50	1734.3	MIOLT-17A	1478.9	MIOLT-17B	1188.2	MIOLT-10C	1732.38	1477.22	1187.81	1723	1428.8	1187.6	1.007	1.035	1.001	1.0011	1.0011	1.0003
55	1991.4	MIOLT-10A	1697.4	MIOLT-17B	1376.8	MIOLT-12C				1991.5	1647.2	1377.7	1.000	1.031	0.999			
60	2257.8	MIOLT-10A	1916.9	MIOLT-17B	1577.2	MIOLT-12C	2257.79	1915.18	1574.47	2257.8	1881.8	1578.7	1.000	1.019	0.999	1.0000	1.0009	1.0018
65	2522.0	MIOLT-12A	2134.3	MIOLT-17B	1777.6	MIOLT-12C				2522.2	2119.9	1778.5	1.000	1.007	0.999			
70	2803.6	MIOLT-12A	2355.9	MIOLT-12B	1976.6	MIOLT-11C	2802.34	2354.81	1972.25	2803.7	2356.5	1977	1.000	1.000	1.000	1.0005	1.0005	1.0022
75	3083.0	MIOLT-12A	2590.6	MIOLT-12B	2181.4	MIOLT-11C				3083.5	2591.7	2181.4	1.000	1.000	1.000			
80	3361.4	MIOLT-12A	2824.6	MIOLT-12B	2386.7	MIOLT-13C	3361.44	2824.57	2383.90	3361.5	2825.4	2388	1.000	1.000	0.999	1.0000	1.0000	1.0012
85	3637.9	MIOLT-12A	3069.6	MIOLT-15B	2600.2	MIOLT-13C				3638	3069.6	2601.4	1.000	1.000	1.000			
90	3926.6	MIOLT-15A	3365.7	MIOLT-15B	2812.3	MIOLT-13C	3925.27	3364.51	2811.61	3926.8	3365.8	2813.8	1.000	1.000	0.999	1.0003	1.0003	1.0003
95	4269.9	MIOLT-15A	3659.9	MIOLT-15B	3049.9	MIOLT-15C				4270.5	3660.4	3050.4	1.000	1.000	1.000			
100	4612.3	MIOLT-15A	3953.4	MIOLT-15B	3294.5	MIOLT-15C	4612.30	3953.40	3294.50	4612.4	3953.5	3294.6	1.000	1.000	1.000	1.0000	1.0000	1.0000
105	4952.6	MIOLT-15A	4245.1	MIOLT-15B	3537.6	MIOLT-15C				4952.6	4245.1	3537.6	1.000	1.000	1.000			
110	5291.0	MIOLT-15A	4535.1	MIOLT-15B	3779.3	MIOLT-15C	5290.99	4535.14	3779.28	5291.3	4535.4	3779.5	1.000	1.000	1.000	1.0000	1.0000	1.0000
115	5627.5	MIOLT-15A	4823.6	MIOLT-15B	4019.7	MIOLT-15C				5629.1	4824.3	4020.3	1.000	1.000	1.000			
120	6012.5	MIOLT-18A	5128.3	MIOLT-18B	4259.8	MIOLT-15C	6012.54	5128.34	4258.84	5975.3	5112	4260	1.006	1.003	1.000	1.0000	1.0000	1.0002
125	6412.9	MIOLT-18A	5469.8	MIOLT-18B	4526.8	MIOLT-18C				6360.7	5424.9	4498.7	1.008	1.008	1.006			
130	6811.3	MIOLT-18A	5809.7	MIOLT-18B	4808.0	MIOLT-18C	6811.33	5809.66	4808.00	6744.5	5752.2	4736.5	1.010	1.010	1.015	1.0000	1.0000	1.0000
135	7208.1	MIOLT-18A	6148.1	MIOLT-18B	5088.1	MIOLT-18C				7126.7	6078.3	4973.4	1.011	1.011	1.023			
140	7604.5	MIOLT-18A	6486.2	MIOLT-18B	5367.9	MIOLT-18C	7602.75	6484.70	5366.65	7507.5	6403.1	5209.4	1.013	1.013	1.030	1.0002	1.0002	1.0002
145	7992.2	MIOLT-18A	6822.9	MIOLT-18B	5646.5	MIOLT-18C				7887	6726.8	5444.6	1.014	1.014	1.037			
150	8392.4	MIOLT-18A	7158.2	MIOLT-18B	5924.0	MIOLT-18C	8387.62	7154.15	5920.67	8265.1	7049.3	5679.1	1.015	1.015	1.043	1.0006	1.0006	1.0006
155	8784.0	MIOLT-18A	7492.3	MIOLT-18B	6200.5	MIOLT-18C				8642	7370.7	5912.8	1.016	1.016	1.049			
160	9174.3	MIOLT-18A	7825.2	MIOLT-18B	6476.0	MIOLT-18C	9166.62	7818.59	6470.55	9017.6	7691.2	6145.7	1.017	1.017	1.054	1.0008	1.0008	1.0008
165	9563.3	MIOLT-18A	8156.9	MIOLT-18B	6750.6	MIOLT-18C				9392.2	8010.6	6381.7	1.018	1.018	1.058			
170	9951.0	MIOLT-18A	8487.6	MIOLT-18B	7024.2	MIOLT-18C	9940.35	8478.53	7016.72	9765.6	8329.2	6617.4	1.019	1.019	1.061	1.0011	1.0011	1.0011
175	10338.1	MIOLT-18A	8817.8	MIOLT-18B	7297.5	MIOLT-18C				10138.1	8646.9	6852.5	1.020	1.020	1.065			
180	10724.6	MIOLT-18A	9147.5	MIOLT-18B	7570.3	MIOLT-18C	10709.32	9134.42	7559.52	10509.5	8963.7	7087	1.020	1.021	1.068	1.0014	1.0014	1.0014
185	11110.1	MIOLT-18A	9476.2	MIOLT-18B	7842.4	MIOLT-18C				10880	9279.7	7320.9	1.021	1.021	1.071			
190	11494.5	MIOLT-18A	9804.1	MIOLT-18B	8113.8	MIOLT-18C	11474.00	9786.64	8099.29	11249.6	9594.9	7554.2	1.022	1.022	1.074	1.0018	1.0018	1.0018
195	11877.9	MIOLT-18A	10131.2	MIOLT-18B	8384.4	MIOLT-18C				11618.3	9909.4	7792.1	1.022	1.022	1.076			
200	12260.4	MIOLT-18A	10457.4	MIOLT-18B	8654.4	MIOLT-18C	12234.77	10435.54	8636.31	11986.2	10223.2	8038.9	1.023	1.023	1.077	1.0021	1.0021	1.0021

Note: Needed to add a 1/20th point near midspan

Table 23. Shear table comparing new BridgeOV overload values with Virtis

1	New BridgeOV Calculated Values (Overload Vehicles Envelope)						Values from Virtis Line Girder Analysis			Original BridgeOV Tables**			Ratio of BridgeOV Tables with New Bridge OV Overload vehicle envelope			Ratio of new BridgeOV with Virtis calculated values		
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Span Length	Shear Envelope of Category A Vehicles	Controlling Vehicle - Category A	Shear Envelope of Category B Vehicles	Controlling Vehicle - Category B	Shear Envelope of Category C Vehicles	Controlling Vehicle - Category C	Virtis Shear Category A	Virtis Shear Category B	Virtis Shear Category C	Moment-BOV Table Category A	Moment-BOV Table Category B	Moment-BOV Table Category C	Calculated /BOV Table Category A	Calculated /BOV Table Category B	Calculated /BOV Table Category C	Calculated / Virtis Category A	Calculated /Virtis Category B	Calculated /Virtis Category C
15	101.7	MIOLT-12A	87.9	MIOLT-13B	76.6	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
20	113.1	MIOLT-05A	98.0	MIOLT-05B	83.7	MIOLT-11C	113.10	98.02	83.72	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
25	123.8	MIOLT-07A	105.5	MIOLT-05B	91.7	MIOLT-04C				n/a	n/a	n/a	n/a	n/a	n/a			
30	133.1	MIOLT-07A	110.4	MIOLT-05B	98.8	MIOLT-03C	133.05	110.41	98.80	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
35	139.7	MIOLT-07A	116.3	MIOLT-08B	105.9	MIOLT-03C				n/a	n/a	n/a	n/a	n/a	n/a			
40	150.2	MIOLT-12A	126.2	MIOLT-12B	111.2	MIOLT-03C	150.15	126.25	111.15	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
45	160.3	MIOLT-12A	134.7	MIOLT-12B	114.7	MIOLT-03C				n/a	n/a	n/a	n/a	n/a	n/a			
50	167.8	MIOLT-12A	141.1	MIOLT-12B	119.5	MIOLT-11C	167.83	141.08	119.47	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
55	173.8	MIOLT-12A	146.1	MIOLT-12B	124.3	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
60	178.5	MIOLT-12A	150.1	MIOLT-12B	128.8	MIOLT-13C	178.54	150.07	128.85	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
65	182.4	MIOLT-12A	153.3	MIOLT-12B	132.6	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
70	185.6	MIOLT-12A	158.7	MIOLT-15B	135.7	MIOLT-13C	185.59	158.74	135.68	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
75	191.8	MIOLT-15A	164.4	MIOLT-15B	138.3	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
80	197.4	MIOLT-15A	169.2	MIOLT-15B	141.0	MIOLT-15C	197.44	169.23	141.03	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
85	202.3	MIOLT-15A	173.4	MIOLT-15B	144.5	MIOLT-15C				n/a	n/a	n/a	n/a	n/a	n/a			
90	206.5	MIOLT-15A	177.0	MIOLT-15B	147.5	MIOLT-15C	206.49	177.00	147.50	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
95	210.4	MIOLT-16A	180.1	MIOLT-15B	150.1	MIOLT-15C				n/a	n/a	n/a	n/a	n/a	n/a			
100	215.0	MIOLT-18A	183.4	MIOLT-18B	152.4	MIOLT-15C	214.98	183.37	152.41	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
105	220.4	MIOLT-18A	188.0	MIOLT-18B	155.5	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
110	225.2	MIOLT-18A	192.1	MIOLT-18B	158.9	MIOLT-18C	225.18	192.05	158.94	n/a	n/a	n/a	n/a	n/a	n/a	0.9999	1.0000	1.0000
115	229.5	MIOLT-18A	195.7	MIOLT-18B	162.0	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
120	233.4	MIOLT-18A	199.0	MIOLT-18B	164.7	MIOLT-18C	233.35	199.03	164.72	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
125	236.9	MIOLT-18A	202.0	MIOLT-18B	167.2	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
130	240.0	MIOLT-18A	204.7	MIOLT-18B	169.4	MIOLT-18C	240.04	204.74	169.44	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
135	242.9	MIOLT-18A	207.2	MIOLT-18B	171.5	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
140	245.6	MIOLT-18A	209.5	MIOLT-18B	173.3	MIOLT-18C	245.57	209.46	173.34	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
145	248.0	MIOLT-18A	211.5	MIOLT-18B	175.0	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
150	250.2	MIOLT-18A	213.4	MIOLT-18B	176.6	MIOLT-18C	250.20	213.40	176.61	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
155	252.2	MIOLT-18A	215.1	MIOLT-18B	178.0	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
160	254.1	MIOLT-18A	216.7	MIOLT-18B	179.4	MIOLT-18C	254.11	216.74	179.37	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
165	255.8	MIOLT-18A	218.2	MIOLT-18B	180.6	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
170	257.4	MIOLT-18A	219.6	MIOLT-18B	181.7	MIOLT-18C	257.44	219.58	181.73	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
175	258.9	MIOLT-18A	220.9	MIOLT-18B	182.8	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
180	260.3	MIOLT-18A	222.0	MIOLT-18B	183.7	MIOLT-18C	260.31	222.03	183.75	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
185	261.6	MIOLT-18A	223.1	MIOLT-18B	184.7	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
190	262.8	MIOLT-18A	224.1	MIOLT-18B	185.5	MIOLT-18C	262.78	224.14	185.49	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
195	263.9	MIOLT-18A	225.1	MIOLT-18B	186.3	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
200	264.9	MIOLT-18A	226.0	MIOLT-18B	187.0	MIOLT-18C	264.94	225.98	187.02	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000

**Note: For shear, there were no original BridgeOV values

Table 24. Shear (2 equal spans) table comparing New BridgeOV overload values with Virtis

1	New BridgeOV Calculated Values (Overload Vehicles Envelope)						Values from Virtis Line Girder Analysis			Original BridgeOV Tables**			Ratio of BridgeOV Tables with New Bridge OV Overload vehicle envelope			Ratio of new BridgeOV with Virtis calculated values		
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Span Length	Shear (2-span) Envelope of Category A Vehicles	Controlling Vehicle - Category A	Shear (2-span) Envelope of Category B Vehicles	Controlling Vehicle - Category B	Shear (2-span) Envelope of Category C Vehicles	Controlling Vehicle - Category C	Virtis Shear Category A	Virtis Shear Category B	Virtis Shear Category C	Moment-BOV Table Category A	Moment-BOV Table Category B	Moment-BOV Table Category C	Calculated /BOV Table Categ A	Calculated /BOV Table Categ B	Calculated /BOV Table Categ B	Calculated / Virtis Category A	Calculated / Virtis Category B	Calculated / Virtis Category C
15	107.8	MIOLT-13A	93.4	MIOLT-13B	81.4	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
20	120.1	MIOLT-05A	104.1	MIOLT-05B	88.7	MIOLT-11C	120.03	104.03	88.74	n/a	n/a	n/a	n/a	n/a	n/a	1.0006	1.0005	1.0000
25	131.2	MIOLT-07A	112.0	MIOLT-05B	97.4	MIOLT-04C				n/a	n/a	n/a	n/a	n/a	n/a			
30	141.3	MIOLT-07A	121.2	MIOLT-11B	105.2	MIOLT-11C				n/a	n/a	n/a	n/a	n/a	n/a			
35	148.8	MIOLT-09A	126.6	MIOLT-11B	112.3	MIOLT-03C				n/a	n/a	n/a	n/a	n/a	n/a			
40	161.7	MIOLT-12A	135.9	MIOLT-12B	118.1	MIOLT-03C	161.66	135.92	118.10	n/a	n/a	n/a	n/a	n/a	n/a	1.0000	1.0000	1.0000
45	173.1	MIOLT-12A	145.5	MIOLT-12B	122.0	MIOLT-12C				n/a	n/a	n/a	n/a	n/a	n/a			
50	181.4	MIOLT-12A	152.4	MIOLT-12B	127.8	MIOLT-11C				n/a	n/a	n/a	n/a	n/a	n/a			
55	187.6	MIOLT-12A	157.7	MIOLT-12B	134.0	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
60	192.4	MIOLT-12A	161.8	MIOLT-12B	139.0	MIOLT-13C	192.30	161.63	138.82	n/a	n/a	n/a	n/a	n/a	n/a	1.0008	1.0007	1.0010
65	196.2	MIOLT-12A	165.7	MIOLT-15B	142.9	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
70	202.0	MIOLT-15A	173.2	MIOLT-15B	146.1	MIOLT-13C				n/a	n/a	n/a	n/a	n/a	n/a			
75	209.2	MIOLT-15A	179.4	MIOLT-15B	149.5	MIOLT-15C				n/a	n/a	n/a	n/a	n/a	n/a			
80	215.3	MIOLT-15A	184.5	MIOLT-15B	153.8	MIOLT-15C	215.07	184.34	153.62	n/a	n/a	n/a	n/a	n/a	n/a	1.0010	1.0010	1.0010
85	220.3	MIOLT-15A	188.9	MIOLT-15B	157.4	MIOLT-15C				n/a	n/a	n/a	n/a	n/a	n/a			
90	224.6	MIOLT-15A	192.5	MIOLT-15B	160.4	MIOLT-15C				n/a	n/a	n/a	n/a	n/a	n/a			
95	228.9	MIOLT-18A	195.7	MIOLT-15B	163.1	MIOLT-15C				n/a	n/a	n/a	n/a	n/a	n/a			
100	235.6	MIOLT-18A	200.9	MIOLT-18B	166.3	MIOLT-18C	235.38	200.76	166.15	n/a	n/a	n/a	n/a	n/a	n/a	1.0009	1.0009	1.0009
105	241.4	MIOLT-18A	205.9	MIOLT-18B	170.4	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
110	246.5	MIOLT-18A	210.3	MIOLT-18B	174.0	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
115	251.0	MIOLT-18A	214.1	MIOLT-18B	177.2	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
120	255.0	MIOLT-18A	217.5	MIOLT-18B	180.0	MIOLT-18C	254.77	217.31	179.84	n/a	n/a	n/a	n/a	n/a	n/a	1.0010	1.0010	1.0010
125	258.6	MIOLT-18A	220.6	MIOLT-18B	182.5	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
130	261.7	MIOLT-18A	223.2	MIOLT-18B	184.8	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
135	264.6	MIOLT-18A	225.7	MIOLT-18B	186.7	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
140	267.1	MIOLT-18A	227.8	MIOLT-18B	188.5	MIOLT-18C	266.80	227.57	188.33	n/a	n/a	n/a	n/a	n/a	n/a	1.0011	1.0010	1.0011
145	269.4	MIOLT-18A	229.7	MIOLT-18B	190.1	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
150	271.4	MIOLT-18A	231.5	MIOLT-18B	191.6	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
155	273.3	MIOLT-18A	233.1	MIOLT-18B	192.9	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
160	274.9	MIOLT-18A	234.5	MIOLT-18B	194.1	MIOLT-18C	274.63	234.24	193.86	n/a	n/a	n/a	n/a	n/a	n/a	1.0011	1.0011	1.0010
165	276.4	MIOLT-18A	235.8	MIOLT-18B	195.1	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
170	277.8	MIOLT-18A	237.0	MIOLT-18B	196.1	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
175	279.1	MIOLT-18A	238.0	MIOLT-18B	197.0	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
180	280.2	MIOLT-18A	239.0	MIOLT-18B	197.8	MIOLT-18C	280.02	238.84	197.66	n/a	n/a	n/a	n/a	n/a	n/a	1.0006	1.0006	1.0006
185	281.2	MIOLT-18A	239.9	MIOLT-18B	198.5	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
190	282.2	MIOLT-18A	240.7	MIOLT-18B	199.2	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
195	283.1	MIOLT-18A	241.4	MIOLT-18B	199.8	MIOLT-18C				n/a	n/a	n/a	n/a	n/a	n/a			
200	283.8	MIOLT-18A	242.1	MIOLT-18B	200.4	MIOLT-18C	283.55	241.85	200.16	n/a	n/a	n/a	n/a	n/a	n/a	1.0011	1.0011	1.0010

**Note: For shear, there were no original BridgeOV values

6.1.4 Adding the Maximum Span Length

As described in Section 5.1.6 and 5.1.7, the NBI maximum span length item 48 can be used to pass some longer vehicles on shorter bridges. BridgeOV was modified to allow for an upper span range. When this value is set, BridgeOV will only analyze values up to that span length.

6.1.5 Interface Features

BridgeOV was originally written when graphical user interfaces were less common and more cumbersome to write and maintain. The updated software is written in the Microsoft .NET programming environment and is able to take advantage of graphing and user interface features that are intrinsic to that environment. The following features have been added to the BridgeOV software:

- Graphical plotting of the vehicle curve as compared to the Class A, B, and C curves.
- Input using a GUI (graphical user interface).
- Loading of multiple vehicles at one time for comparative plotting.
- Envelope plotting of multiple vehicles.
- Several windows of BridgeOV can be opened at once.
- Graphs can be copied to the clipboard and pasted in other documents.
- Data grids can be copied to the clipboard and pasted into spreadsheets.

The features above were vital to this research; all of the graphs produced in this document were created using the BridgeOV software. The software is delivered as part of this project and will continue to be of value to MDOT bridge engineers.

6.2 Discussion of Results

The BridgeOV software continues to be a useful tool, and the upgrades to include shear and enhanced interface features will make the tool even more useful. This software, coupled with the PVA software discussed in Section 5.1.1 of this document, provides a mini-toolbox for periodically reviewing and analyzing permit vehicle lists provided by the TPU or weigh-in-motion (WIM) data.

6.3 Conclusions/Recommendations

Based on the results of this section and of the previous sections where heavier permit vehicles are reviewed using the revised algorithm, it is recommended that the revised BridgeOV program be implemented as part of the overall Permit Rating analysis process. The BridgeOV algorithm has been integrated into the BridgeOV-Virtis software

which will run BridgeOV if the bridge in question is not present in the Virtis database. A flowchart describing the overall process is provided in Figure 79 and Figure 80.

7 Final Conclusions

Based on the research presented, the following is a summary of the conclusions of this research:

Phased approach Michigan is a Virtis state and is currently inputting many of the state Bridge structures into Virtis. Rating bridges based on real world analysis taking into account recent condition changes provide the best rating possibility. However, until all bridges can be entered into Virtis and the data validated, a phased approach using a version of BridgeOV as a substitute for Virtis can be used. This approach is implemented in the API described in '**Appendix G – BridgeOV-Virtis Application Programming Interface (API) interface**'.

The phased approach flowchart is shown in **Figure 79** and **Figure 80**

Analysis of vehicles A review of a yearly list of 16,000+ permit vehicles provided some insight into the size of vehicles being permitted on Michigan roads. This list was reviewed and sorted using a variety of methods outlined in Section 5 of this document comparing the results of this analysis with those of the Michigan Overload vehicles. This analysis provides a benchmark for future review of Michigan permit vehicles.

Using the NBI maximum span length For non-Virtis structures (i.e. structures that are analyzed using in BridgeOV), it was determined that the NBI data item describing maximum span length could be used to pass some shorter span structures for vehicles that are longer in length.

Vehicle anomalies During the review of the permit vehicle data it was discovered that some of the data appeared anomalous (e.g. axle spacing of 4 inches). This data may be the result of typos in the permit entry process.

BridgeOV-LFR vs. LRFR LRFR capabilities were added to BridgeOV by incorporating Equation 18 of the Curtis/Till research provided by MDOT (see 'References' section). Upon reviewing a simple 3 axle vehicle, it was noted that in shorter spans, the factored moment of a heavier vehicle could be less than a lighter vehicle even though the trucks were of the same length. This was attributable to the different load factors, which are a function of the weight and include probability, calculated for the vehicles.

In addition, when reviewing the other vehicles analyzed in this section using the LRFR revision to BridgeOV, it was noted that for shorter span bridges, LRFR passes vehicles that would otherwise fail using the LFR option.

8 Recommendations for Implementation

The following sections provide recommendations for implementing the results of research provided in this document.

8.1 *Implement the API*

The BridgeOV-Virtis API as described in Appendix G should be implemented in the MiTRIP routing software. In addition to the documentation provided in Appendix G, the BridgeOV-Virtis application delivered with this project provides an example of its implementation. The API is described in more detail in Figure 79 and Figure 80, but the highlights include:

- A phased approach, where a BridgeOV analysis is used when a bridge is not present in the Virtis database.
- Using the NBI maximum span length for cases where BridgeOV is used for the analysis.
- Simple span shear and 2 equal span shear checks added to BridgeOV.
- The API allows for the use of the LFR or LRFR (MDOT version based on Curtis/Till load factors). The current default and the researchers recommendation is to use the LFR option.
- Virtis bridges can be added to the process at any time.

8.2 *Virtis Database Development*

The researchers recommend the continued development of the MDOT Virtis database. While the tools provided with this research project will work without the Virtis software and are an improvement over the previous version of the BridgeOV, the overall recommendation is to provide as much analysis in the Virtis software as possible. Virtis provides a more refined analysis/rating of bridges that cannot be performed by data

available in the NBI bridge records. MDOT is currently a Virtis licensee and user state and continues to input more bridges into the Virtis system. As more and more bridges become available in the Virtis database, a more accurate assessment of bridge rating for overload permits will be possible.

During the development of the database, methods described in the software user manual section of this document for increasing the efficiency of the Virtis analysis (see Section 10.2.3) should be followed. Prioritization of the bridges entered into Virtis and used by the permitting database should take place. 'Problem' bridges (i.e. ones in which permit rating issues have arisen in the past)

8.3 Periodic Use of the Software Tools

Several tools were developed for this research project that can continue to be used by the MDOT bridge group in coming years for the periodic analysis of permit vehicles and WIM data. Using the PVA software and standalone BridgeOV software developed for this project, the most current vehicle data can be analyzed annually to determine trends in vehicle loads using the data provided in this report as a benchmark. This includes an annual review of the permit vehicle list (and possibly WIM data) by sorting the data using the software according to axle concentration and maximum gross weight. Envelope curves produced by the BridgeOV-Standalone tool can be compared to previous years to track any trends in vehicle loading.

8.4 Implementation of Training Course

A four hour training course was developed and presented to MDOT as part of this research project. The course covers the use of the software developed for this project and was designed to be presented to others learning to use the software. MDOT can use this training material as a tutorial to present the software use to others.

9 Recommendations for Further Research

The software tools developed for this project allow for additional research by MDOT staff. The following is a list of suggested future research:

- Periodic reviews of the permit vehicle data using the PVA software tool along with the BridgeOV-Standalone tool. Efforts should be made to compare future data using these tools with the benchmarks set in this research.
- Review of the LRFR load factors as calculated using equation 18 of the Curtis/Till research to determine if the behavior described in this report was expected or anomalous.
- Review of MDOT WIM data using the software tools created for this project.

10 BridgeOV Software User Manual

This section serves as a User Manual or Guide for the BridgeOV software. The software has three primary sections:

- Running BridgeOV standalone
- Running BridgeOV with Virtis
- Tool for analyzing permit vehicle axle configurations

Each of these will be described in the following sections along with some tips of for preparing the Virtis Database to optimize the use of the BridgeOV/Virtis portion of the software.

Appendix F provides a description of BridgeOV file that stores the Class A, B, and C moments and shears that are used to compare the calculated moments and shears.

Appendix G provides a description of the BridgeOV/Virtis API form running the calling the program and interpreting the results from another program (such as MiTRIP).

10.1 Starting the BridgeOV-Virtis program

When starting the BridgeOV-Virtis program, the user is prompted for Virtis database information similar to the window when starting the Virtis standalone program. Since the user must connect to the Virtis database in order to analyze bridges in Virtis, the username, password and data source must be provided (see Figure 77). These will be the same values use to login into the Virtis system.

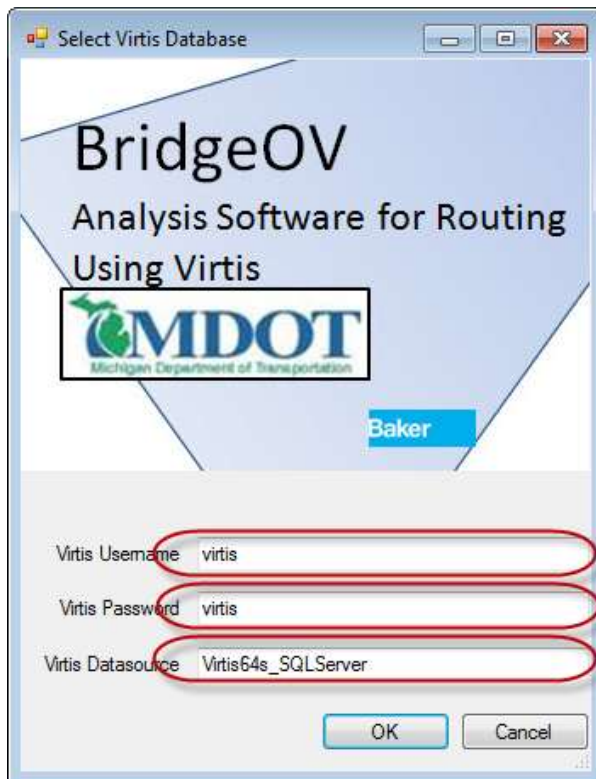


Figure 77. BridgeOV-Virtis login screen

If the user selects 'Cancel', the program will still open and will be able to run the BridgeOV-Virtis (as well as PVA, and the BridgeOV-standalone program), but BridgeOV-Virtis will not be able to analyze bridges from the Virtis database. The 'Login to Virtis' menu option will appear in the 'File' menu for the user to retry the login (see Figure 78).

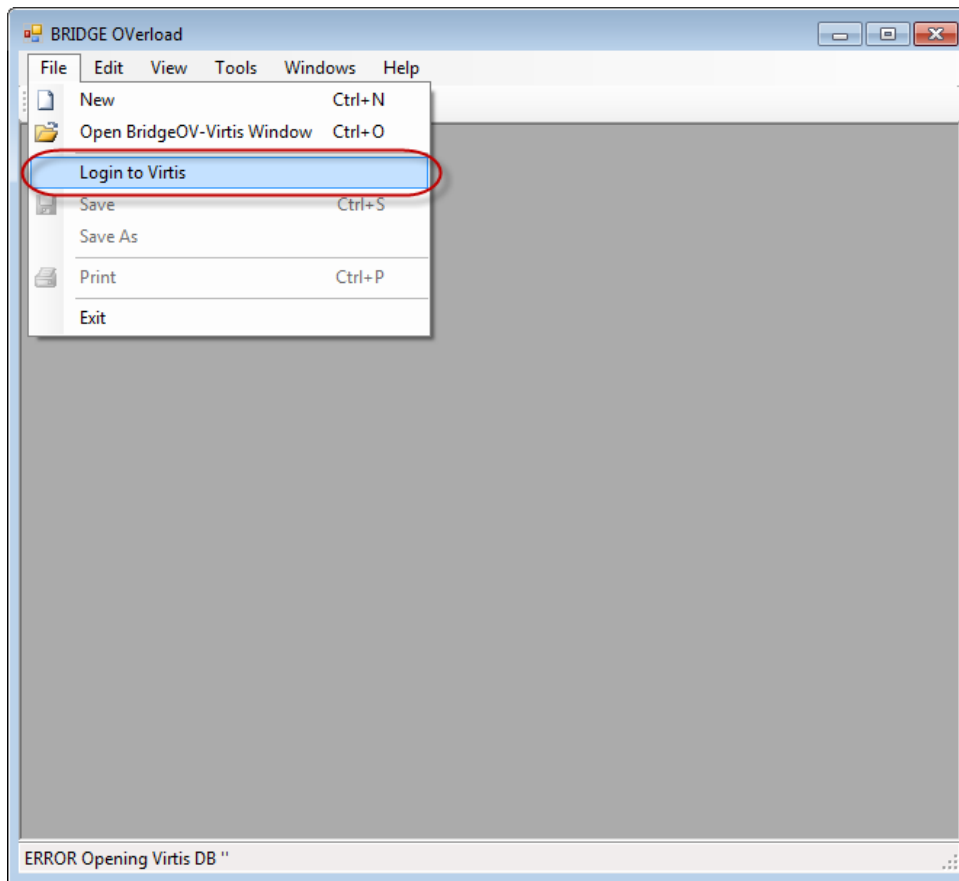


Figure 78. BridgeOV-Virtis option disabled

Once the program is initialized, the following options are available:

- Running BridgeOV-Virtis.
- Running BridgeOV standalone tool.
- Running the Permit analysis tool.

The following sections provide descriptions for each of these.

10.2 BridgeOV/Virtis

The BridgeOV/Virtis program runs BridgeOV and Virtis in a batch mode. The intention is to incorporate the software into the MiTRIP routing software to return PASS/FAIL results. The overall logic of the software is illustrated in Figure 79 and Figure 80.

The program takes the following as input:

- List of bridges described by their NBI bridge id number along with specific bridge parameters including: the ABCD class, the R or S flag, the NBI Maximum span length.
- The vehicle to be analyzed with the specific axle loads, axle spacings and gage distances for each axle.

The details of the above parameters are discussed in the API document provided in Appendix G.

The program attempts to analyze all bridges in Virtis using the vehicle provided. If the bridge is not present in the Virtis database or the Virtis analysis fails for some reason, the program will analyze the bridge and return a PASS/FAIL based on the BridgeOV run. The details of the process are described in the flowcharts provided in Figure 79 and Figure 80.

The following sections provide a description of the interface used to illustrate how the API can be implemented.

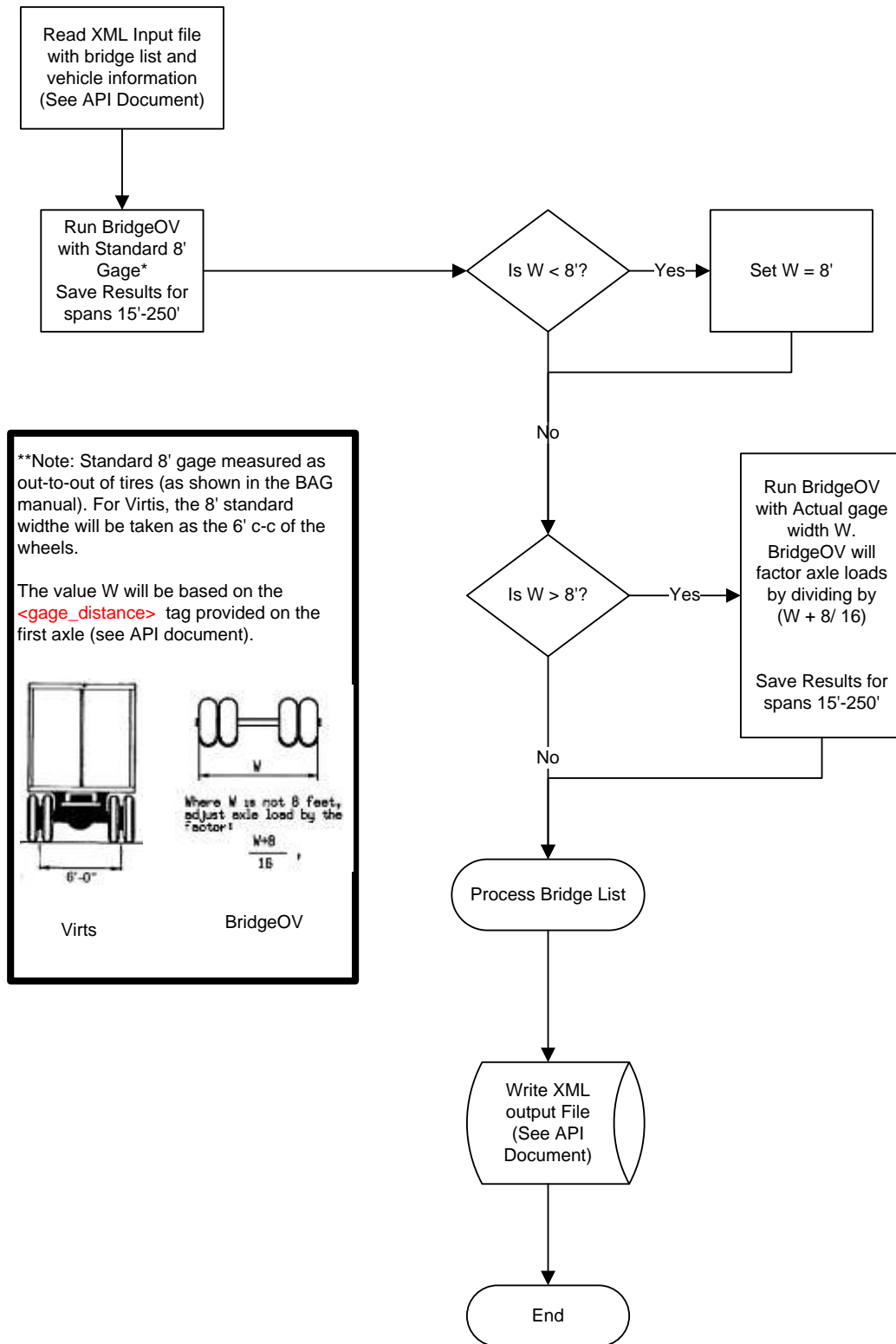


Figure 79. BridgeOV/Virtis logic (Part 1)

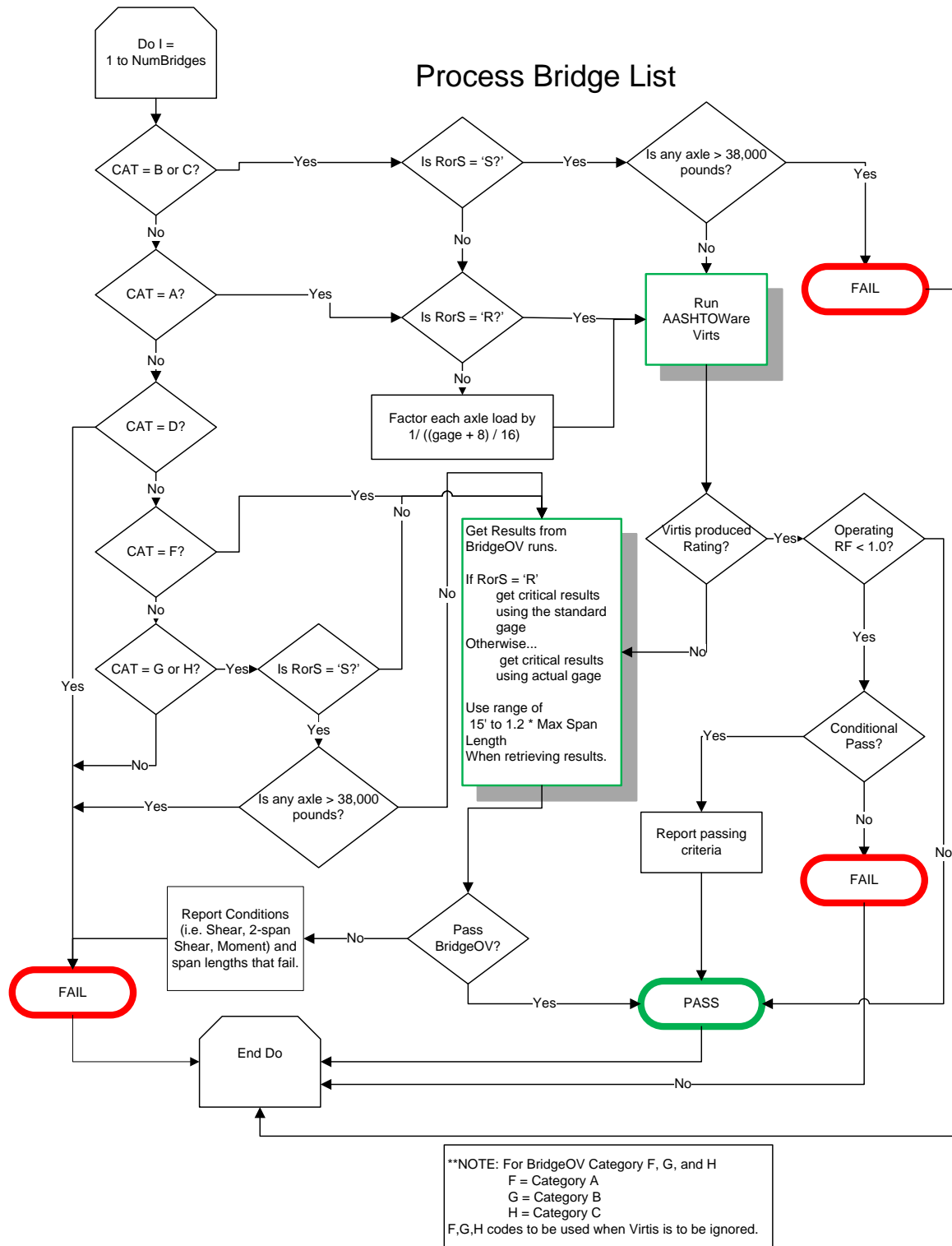


Figure 80. BridgeOV/Virtis logic (Part 2)

10.2.1 Running the BridgeOV/Virtis

To start the BridgeOV/Virtis Interface, click on the 'File-Open BridgeOV-Virtis Window' menu option or the 'File-New' option (see Figure 81).

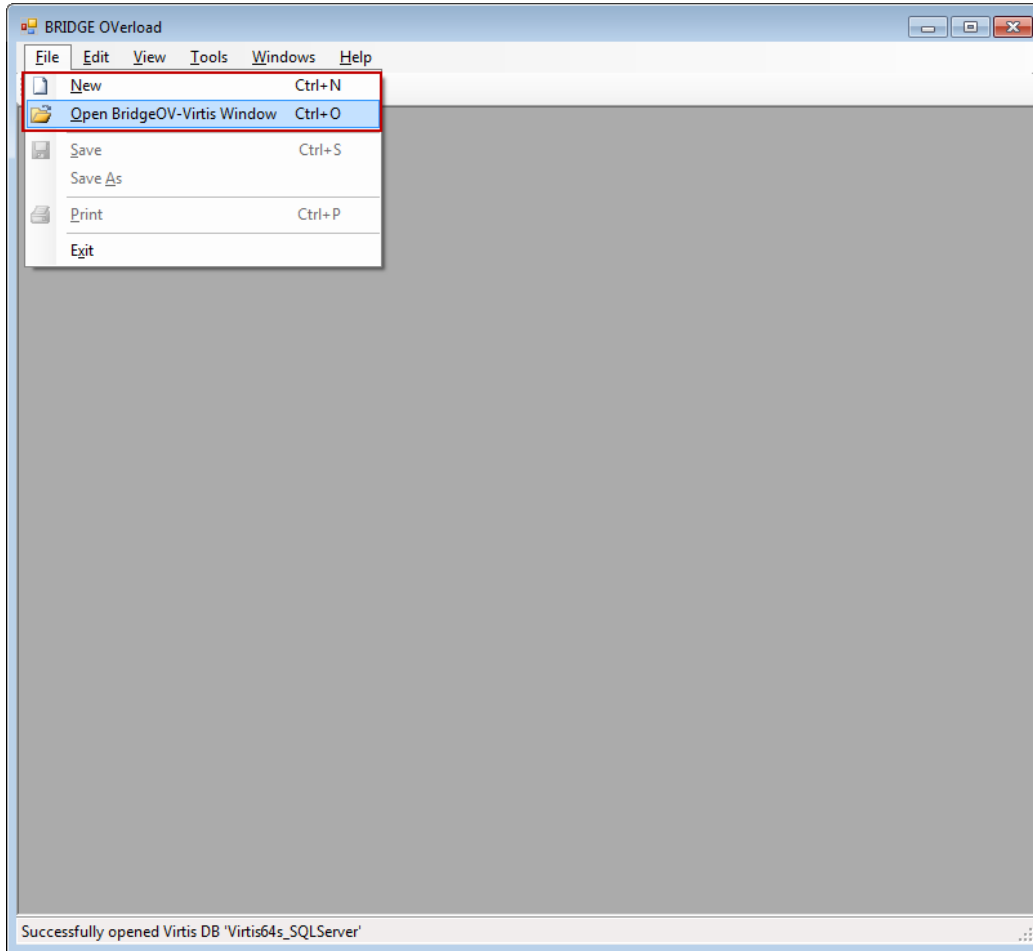


Figure 81. Starting BridgeOV/Virtis

The 'New' option will create a base template of one bridge and one default three-axle vehicle that the user can then modify.

Upon selecting the 'Open' option, the user will be prompted with an open box to browse to a Michigan DOT routing file (*.mdr). This file is in XML format and is described in detail in Appendix G – BridgeOV-Virtis Application Programming Interface (API) interface.

10.2.2 The BridgeOV/Virtis interface

The following sections provide a description of the functionality of the BridgeOV/Virtis interface. This application provides a practical example of the use of the BridgeOV-Virtis API described in 'Appendix G – BridgeOV-Virtis Application Programming Interface (API) interface'.

Open Input

Note that the input information provided on these tabs can be modified and saved or the file can be modified externally and loaded. This can be done by modifying the XML file with an external editor such as Notepad or WordPad and reloading it into BridgeOV-Virtis or by clicking on the 'Open Input' button, modifying the file and clicking on the 'Save' button in the Open window (see Figure 82).

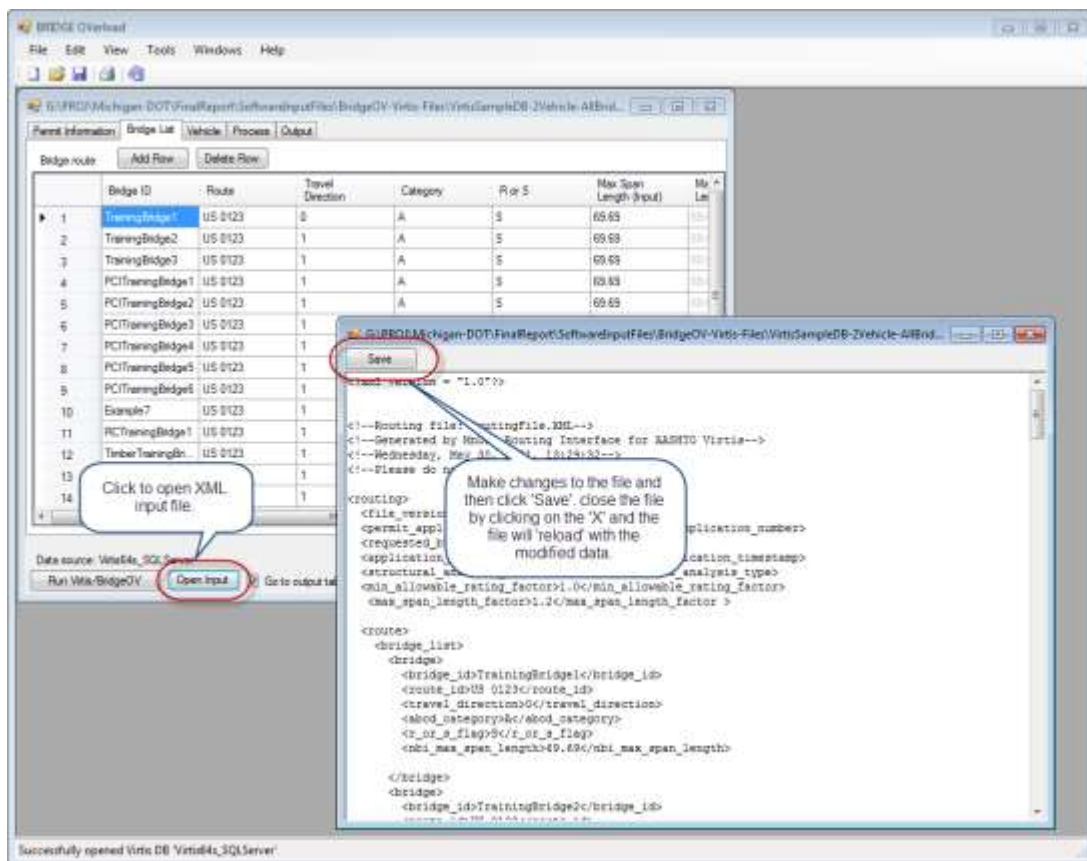


Figure 82. Modifying a BridgeOV-Virtis XML file.

File->Save – File->Save As.

Alternatively, the user may modify the file within the BridgeOV-Virtis environment and either save the file using the pulldown menu 'File-Save' or 'File-Save As'.

NOTE: If a BridgeOV-Virtis file is opened that was prepared externally and contains two or more vehicle definitions, only the first vehicle will be used. A warning message will be supplied but all vehicles beyond the first will be ignored. While the API supports multiple vehicles, this implementation of the API does not.

Go to output tab after analysis

If this box is checked (see Figure 83), the program will pass control to the 'Output' tab immediately after the 'Run Virtis/BridgeOV' process is completed. If this box is not checked, control is returned to the tab visible when the 'Run Virtis/BridgeOV' button was selected. This option along with 'Auto Save' is useful when using BridgeOV-Virtis to interactively view the BridgeOV plots without running Virtis (see Section 10.3.2).

Auto Save (no prompts)

If this box is checked (see Figure 83), BridgeOV-Virtis will automatically save the input currently shown in the window. The user will not be prompted to save the file.

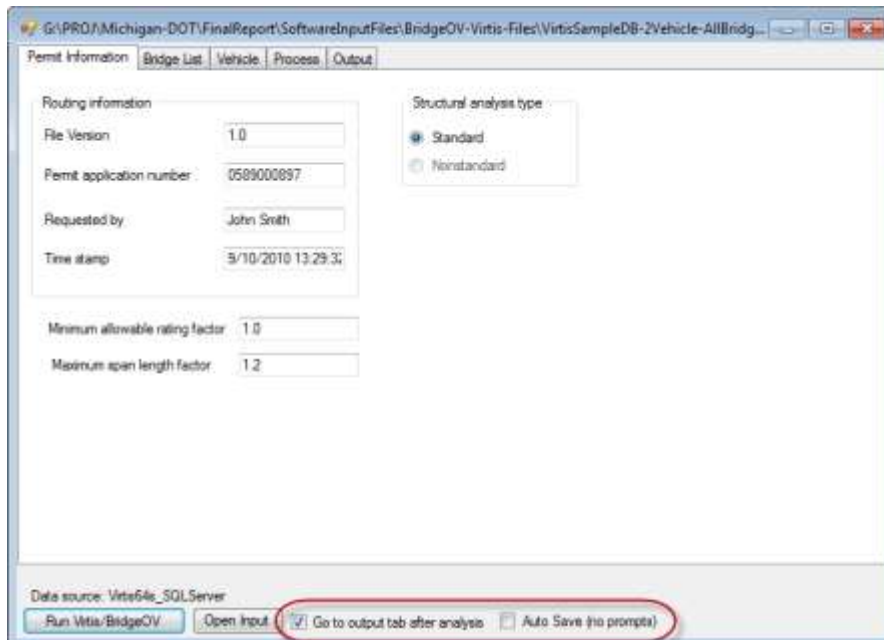


Figure 83. Checkboxes on the BridgeOV-Virtis window

10.2.2.1 Permit Information Tab

Figure 84. BridgeOV-Virtis Permit Information tab

Routing Information

File Version

Indicates the version of the routing request file. Should be 1.0.

Permit application number

Permit application number for tracking purposes.

Requested by

Name of person submitting the routing request file.

Time stamp

Time that the routing request file was created.

Minimum allowable rating factor

Minimum allowable rating factor. Default is 1.00.

Maximum span length factor

This value is multiplied by the `nbi_max_span_length` to set the upper limit of span length for BridgeOV runs.

10.2.2.2 Bridge List Tab

The screenshot shows a software window titled "G:\PROJ\Michigan-DOT\FinalReport\SoftwareInputFiles\BridgeOV-Virtis-Files\VirtisSampleDB-2Vehicle-AllBridg...". The window has tabs for "Permit Information", "Bridge List", "Vehicle", "Process", and "Output". The "Bridge List" tab is active, showing a table with columns: Bridge ID, Route, Travel Direction, Class, R or S, Max Span Length (Input), and Max Length. The table contains 14 rows of data. Below the table are buttons for "Add Row" and "Delete Row", and a "Data source: Virtis64s_SQLServer" label. At the bottom, there are checkboxes for "Run Virtis/BridgeOV", "Open Input", "Go to output tab after analysis", and "Auto Save (no prompts)".

	Bridge ID	Route	Travel Direction	Class	R or S	Max Span Length (Input)	Max Length
1	TrainingBridge1	US 0123	0	A	S	69.69	69.6
2	TrainingBridge2	US 0123	1	A	S	69.69	69.6
3	TrainingBridge3	US 0123	1	A	S	69.69	69.6
4	PCITrainingBridge1	US 0123	1	A	S	69.69	69.6
5	PCITrainingBridge2	US 0123	1	A	S	69.69	69.6
6	PCITrainingBridge3	US 0123	1	A	S	69.69	69.6
7	PCITrainingBridge4	US 0123	1	A	S	69.69	69.6
8	PCITrainingBridge5	US 0123	1	A	S	69.69	69.6
9	PCITrainingBridge6	US 0123	1	A	S	69.69	69.6
10	Example7	US 0123	1	A	S	69.69	69.6
11	RCTrainingBridge1	US 0123	1	A	S	69.69	69.6
12	Timber Training Bri...	US 0123	1	A	S	69.69	69.6
13	FSys GFS Trainin...	US 0123	1	A	S	69.69	69.6
14	FSys FS Training...	US 0123	1	A	S	69.69	69.6

Figure 85. BridgeOV-Virtis Bridge List tab

This tab provides a list of the bridges read in from the XML input file.

The user can Add or Delete bridges by clicking on the 'Add Rows' or 'Delete Rows' button. When the 'Delete Rows' button is selected, the row with the focus (i.e. the one with the little black arrowhead) will be deleted. Added rows are added to the bottom of the list.

Bridge ID

Agency bridge ID. From the NBI record. Virtis uses this to key on finding the bridge in the Virtis DB.

Route

Route ID as listed in the Virtis DB.

Direction

Travel Direction. Default value is 0.

-1/down/down milepost = Down Milepost

1/up/up milepost = Up Milepost

0 = Not Specified

Class

This item is specific to Michigan DOT. This is the MDOT specific NBI code Item 193 Overload class.

The item can have the following options:

A – Run Virtis. If bridge not present in Virtis run BridgeOV with Class A.

B – Run Virtis. If bridge not present in Virtis run BridgeOV with Class B.

C – Run Virtis. If bridge not present in Virtis run BridgeOV with Class C.

D – Bridge fails

F – Run BridgeOV always (i.e. don't try to run Virtis). Use Class A

G – Run BridgeOV always (i.e. don't try to run Virtis) Use Class B.

H – Run BridgeOV always (i.e. don't try to run Virtis) Use Class C.

R or S

This can be any of the following:

R – If running BridgeOV use the standard 8' axle width (i.e. no factoring the axle loads).

Blank – Use the gage specified on the permit request with axle loads that were reduced (increased) to account for gage width. In this case each axle load is divided by

$(\text{gage width} + 8')/16.0$

S – If the bridge is a Class B or C and any axle exceeds 38,000 pounds, fail the bridge. Do not run Virtis or BridgeOV.

Max Span length (input)

This is the length of maximum span for the structure (NBI item 48).

Max Span Length (used)

This is the maximum span length * the maximum span length factor used by BridgeOV.

10.2.2.3 Vehicle Tab

	Axle Weight	Wheel Contact Width	Min. Axle Spacing	Max. Axle Spacing	Gage Distance
▶ 1	32	25	0	-1	8
2	32	20	14	-1	8
3	27	20	14	30	8

Figure 86. BridgeOV-Virtis Vehicle tab

The user can Add or Delete axles by clicking on the 'Add Rows' or 'Delete Rows' button. When the 'Delete Rows' button is selected, the row with the focus will be deleted. Added rows are added to the bottom of the list.

Vehicle Name

Enter a string to describe the name of the vehicle. This will appear in the legend of the BridgeOV plots.

Impact

User defined impact value for the vehicle.

Single lane indicator

Indicates if single lane distribution factors should be used in analysis. Should be either "TRUE" or "FALSE".

Controlling rating level

Indicates rating factor to be checked to determine pass or fail status of rating. Should be either "Inventory" or "Operating".

BridgeOV LRFR run

Checking this flag will turn on the LRFR flag and will run BridgeOV using the LRFR flag. (see Section 10.3.2 for a definition of this flag for BridgeOV). This definition does not affect the Virtis runs; the input for the specification type (LFR/LRFR) is entered and stored in the Virtis database.

View vehicles

Click on this button to view the vehicle loaded in the vehicle list. A window, similar to the one shown below, will open (see Figure 87 below).

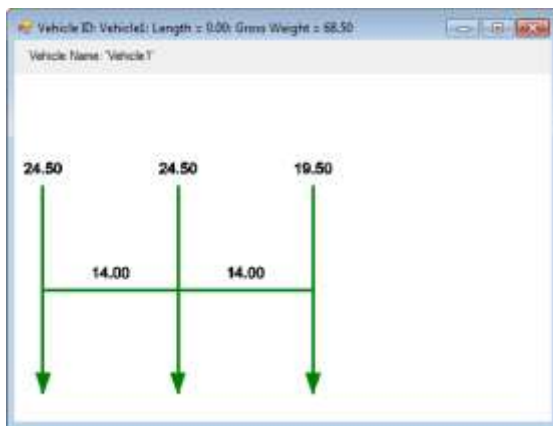


Figure 87. Vehicle view

Import BridgeOV

Clicking this button will prompt the user for the location of an existing BridgeOV input file (see Section 10.3.2). The file will be imported into the 'Vehicle List' datagrid and may be modified after the import.

Export BridgeOV

Clicking this button will prompt the user for the location to export or store a BridgeOV input file (see Section 10.3.2) using the data currently described by the input on this tab. The file can then be opened in the BridgeOV Standalone tool (see Section 10.3).

Vehicle List

Lists axle configuration of the vehicle being analyzed. This application permits one vehicle loaded at a time, but the API provides options for multiple vehicles to be loaded. The datagrid displays the axle weight, wheel contact width, minimum axle spacing, maximum axle spacing, and gage distance. If the axle spacing does not vary, the maximum axle spacing should be input as -1. Varying axle spacing can be used in Virtis, but will not be used for BridgeOV (BridgeOV does not handle variable axle spacing).

10.2.2.4 Process Tab

Clicking on the 'Run Virtis/BridgeOV ' button starts the process of running the list of bridges in the 'Bridge list' using the vehicle provided in the 'Vehicle' tab. The process tab provides (see Figure 88) a running tally of the bridges being analyzed. Depending on the size of the bridge and parameters set in Virtis, this could take some time. Section 10.2.3 discusses some tips for shortening the run time of the bridges in the Virtis database.

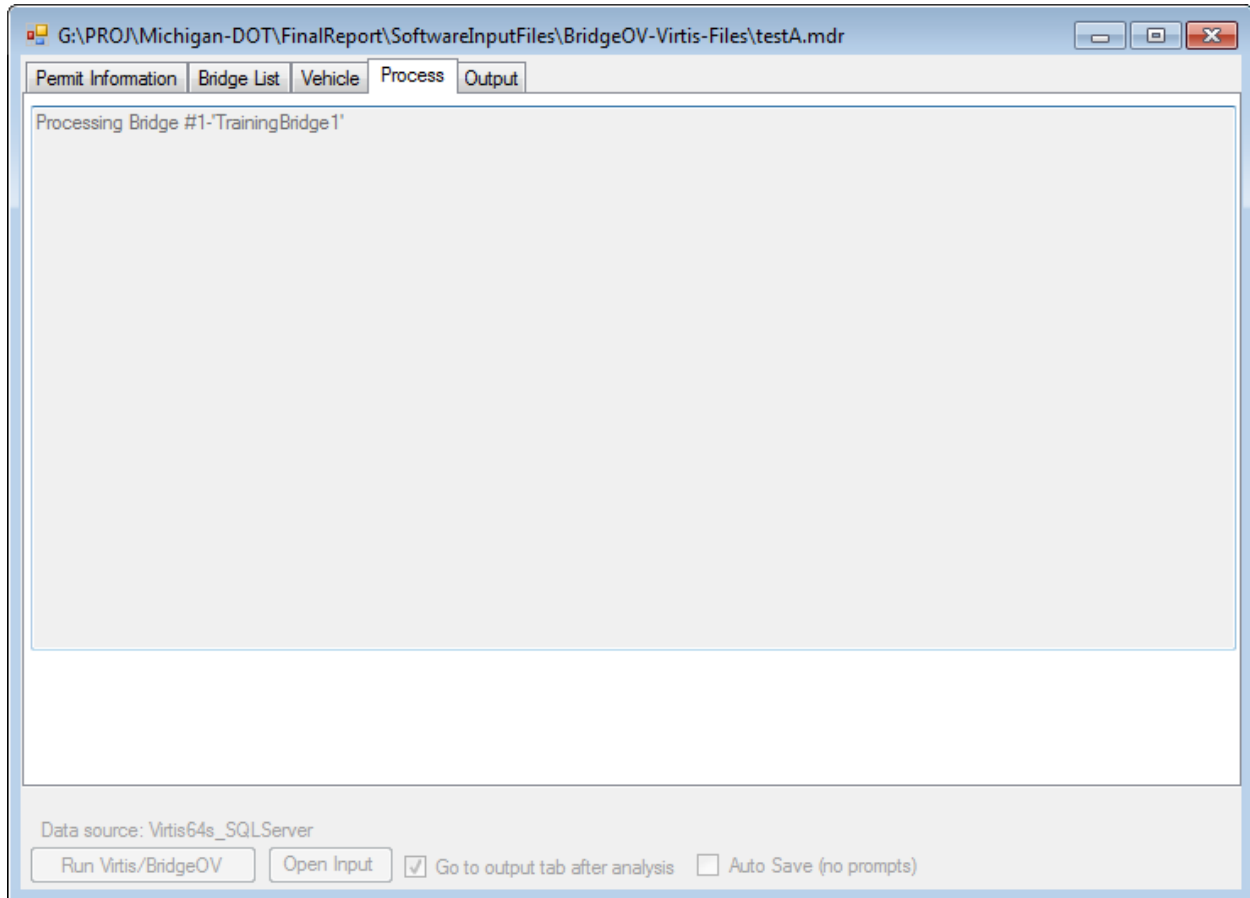


Figure 88. BridgeOV-Virtis Process tab

10.2.2.5 Output Tab

When BridgeOV-Virtis is finished with the analysis, the output tab is displayed. There are several options for view output in this tab.

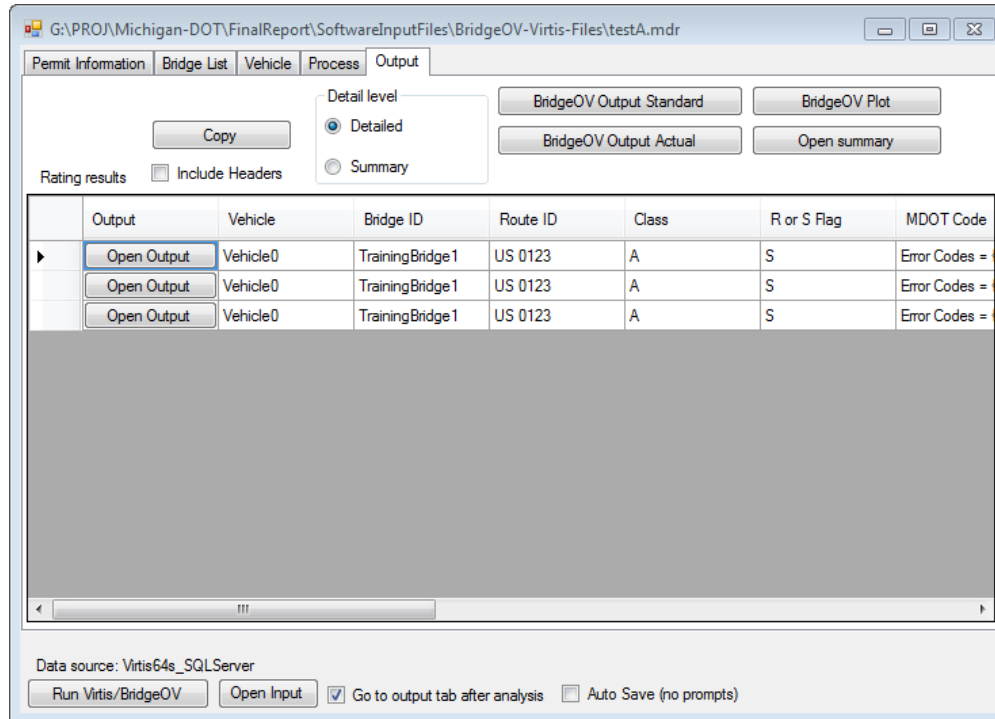


Figure 89. BridgeOV-Virtis Output tab

Open summary

This button opens the main output summary table that is produced by the BridgeOV-Virtis API (see 'Appendix G – BridgeOV-Virtis Application Programming Interface (API) interface' for a description of the output summary)

Detail Level

The rating results table has two options for displaying data – Detailed and Summary. Detailed displays more information and has a button (1st column) to review the output for the bridge as it is returned directly from Virtis.

Detailed Output

Several columns in this table are an echo of the input. Other columns of data include:

Open Output button

This button will open the individual Virtis output file for this bridge and vehicle.

MDOT code

A list of all failures/successes for this bridge/vehicle combination

MDOT Message

A more verbose description of the MDOT code.

Run time

The actual time that it took to analyze this bridge. Useful for modifying the Virtis database to increase speed.

Inventory/Operating RF

These values (if present) are returned from Virtis.

Failed BOV span lengths

A list of all of the span lengths the failed in BridgeOV for this bridge/vehicle combination

Summary Output

This option provides a more concise description of the Detailed Output. The primary difference is the inclusion of a Pass/Fail column and a lesser number of columns than the 'Detailed Output' option.

Copy button

The 'Copy' button will copy the contents of the 'Rating Results' grid to the clipboard. It can then be pasted directly into an Excel spreadsheet where it can be modified and formatted. If the 'Include Headers' checkbox is selected, the clipboard will include the headings from the table.

BridgeOV Output Standard

Clicking this button opens the BridgeOV output file in Notepad for the standard gage (8-ft). If more than one vehicle is present, this will open each vehicle file.

BridgeOV Output Actual

Clicking this button opens the BridgeOV output file in Notepad for the actual gage (8-ft). If more than one vehicle is present, this will open each vehicle file.

BridgeOV Plot

Clicking this button opens the BridgeOV-standalone interface and loads both the with the actual and standard vehicle options. The BridgeOV-Virtis and BridgeOV-Standalone windows are arranged automatically as shown in Figure 90. The options for the BridgeOV-Standalone interface are described in Section 10.3.1.2.

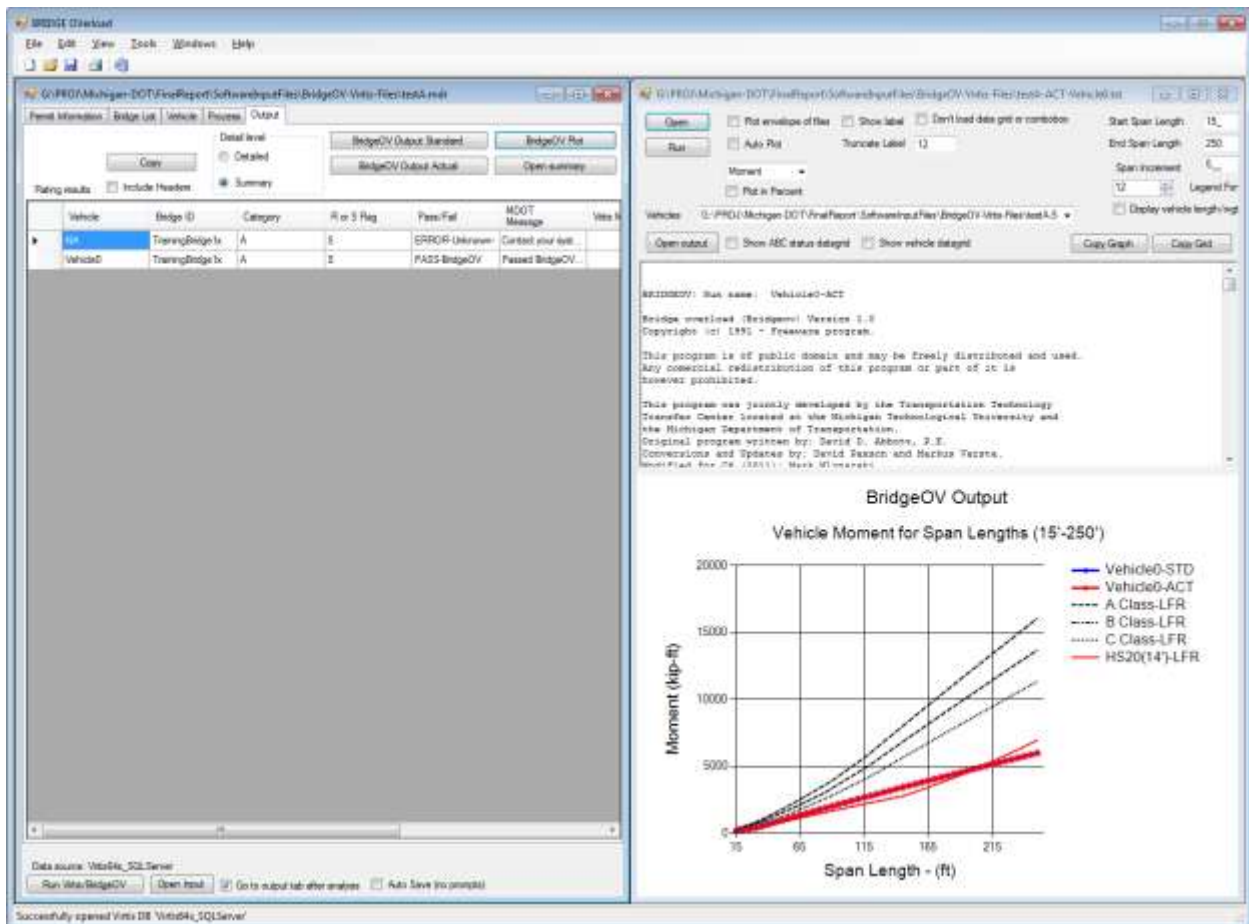


Figure 90. BridgeOV plot with standard gage (STD) and actual gage (ACT)

10.2.3 Setting up the Virtis database

Bridges set up in Virtis may require quite a bit of analysis especially if they are larger structures (i.e. multiple spans) with several girders. Since Virtis analyzes each girder independently, the more girders in the system, the longer the analysis run. This section attempts to provide some tips for reducing the run time of Virtis through and example.

MDOT provided a list of 32 bridges that were primarily multiple span structures with several girders. The following sections provide a step by step process to reduce the run time.

10.2.3.1 Identify the run time

Initially all 32 structures were run through BridgeOV-Virtis with the a 3 axle vehicle (8 kip, 32 kip, 32 kip with 14-ft spacing) and they produced the run time shown in Figure 91. As can be seen, the total run time was almost 2 hours.

```

Processing Bridge #1-'63163192000S010' (Time: 0 hours, 2 min, 49 sec)
Processing Bridge #2-'82182023000S270' (Time: 0 hours, 1 min, 40 sec)
Processing Bridge #3-'82182192000S040' (Time: 0 hours, 0 min, 37 sec)
Processing Bridge #4-'41141064000R020' (Time: 0 hours, 0 min, 10 sec)
Processing Bridge #5-'63163111000R020' (Time: 0 hours, 0 min, 34 sec)
Processing Bridge #6-'19119033000S090' (Time: 0 hours, 0 min, 20 sec)
Processing Bridge #7-'11111016000B013' (Time: 0 hours, 19 min, 20 sec)
Processing Bridge #8-'23123063000S130' (Time: 0 hours, 0 min, 47 sec)
Processing Bridge #9-'82182022000S430' (Time: 0 hours, 3 min, 3 sec)
Processing Bridge #10-'49149025000S050' (Time: 0 hours, 0 min, 24 sec)
Processing Bridge #11-'38138101000S100' (Time: 0 hours, 0 min, 1 sec)
Processing Bridge #12-'50150062000S110' (Time: 0 hours, 4 min, 25 sec)
Processing Bridge #13-'63163191000S010' (Time: 0 hours, 0 min, 36 sec)
Processing Bridge #14-'82182081000S061' (Time: 0 hours, 1 min, 7 sec)
Processing Bridge #15-'50150061000S030' (Time: 0 hours, 1 min, 45 sec)
Processing Bridge #16-'50150061000S140' (Time: 0 hours, 27 min, 51 sec)
Processing Bridge #17-'82182291000B020' (Time: 0 hours, 0 min, 4 sec)
Processing Bridge #18-'63163191000S100' (Time: 0 hours, 2 min, 6 sec)
Processing Bridge #19-'19119043000S020' (Time: 0 hours, 4 min, 56 sec)
Processing Bridge #20-'25125031000S110' (Time: 0 hours, 5 min, 44 sec)
Processing Bridge #21-'58158151000S100' (Time: 0 hours, 7 min, 8 sec)
Processing Bridge #22-'25125132000S230' (Time: 0 hours, 10 min, 4 sec)
Processing Bridge #23-'50150111000S274' (Time: 0 hours, 3 min, 51 sec)
Processing Bridge #24-'82182022000S480' (Time: 0 hours, 2 min, 22 sec)
Processing Bridge #25-'82182022000S420' (Time: 0 hours, 0 min, 36 sec)
Processing Bridge #26-'13113033000B010' (Time: 0 hours, 3 min, 32 sec)
Processing Bridge #27-'82182191000S240' (Time: 0 hours, 7 min, 1 sec)
Processing Bridge #28-'41141027000B020' (Time: 0 hours, 3 min, 22 sec)
Processing Bridge #29-'41141027000B020' (Time: 0 hours, 3 min, 23 sec)
Processing Bridge #30-'a41141064000R020' (Time: 0 hours, 0 min, 0 sec)
Processing Bridge #31-'b41141064000R020' (Time: 0 hours, 0 min, 0 sec)
Processing Bridge #32-'c41141064000R020' (Time: 0 hours, 0 min, 0 sec)
(Total Time: 1 hours, 59 min, 53 sec)

```

Figure 91. Initial run times for 32 multi-span bridges

Looking at the list, several run times are highlighted as being exceptionally long, but several of the bridges run for several minutes or more. All of the bridges in this set were reviewed for reducing the overall run time of the set.

10.2.3.2 Choosing the key members

To determine which members to 'turn-off' when running Virtis, all members must first be analyzed and the rating results reviewed. The example shown here is Bridge #19 (19119043000S020) which required 4 min and 56 sec of analysis time originally to run a 3 axle vehicle with no variable axle spacing. To reduce the run time, Virtis was run for this bridge using the 20 overload Class A vehicles (see Figure 92) and reviewing the rating results by sorting them from highest to lowest (see Figure 93).

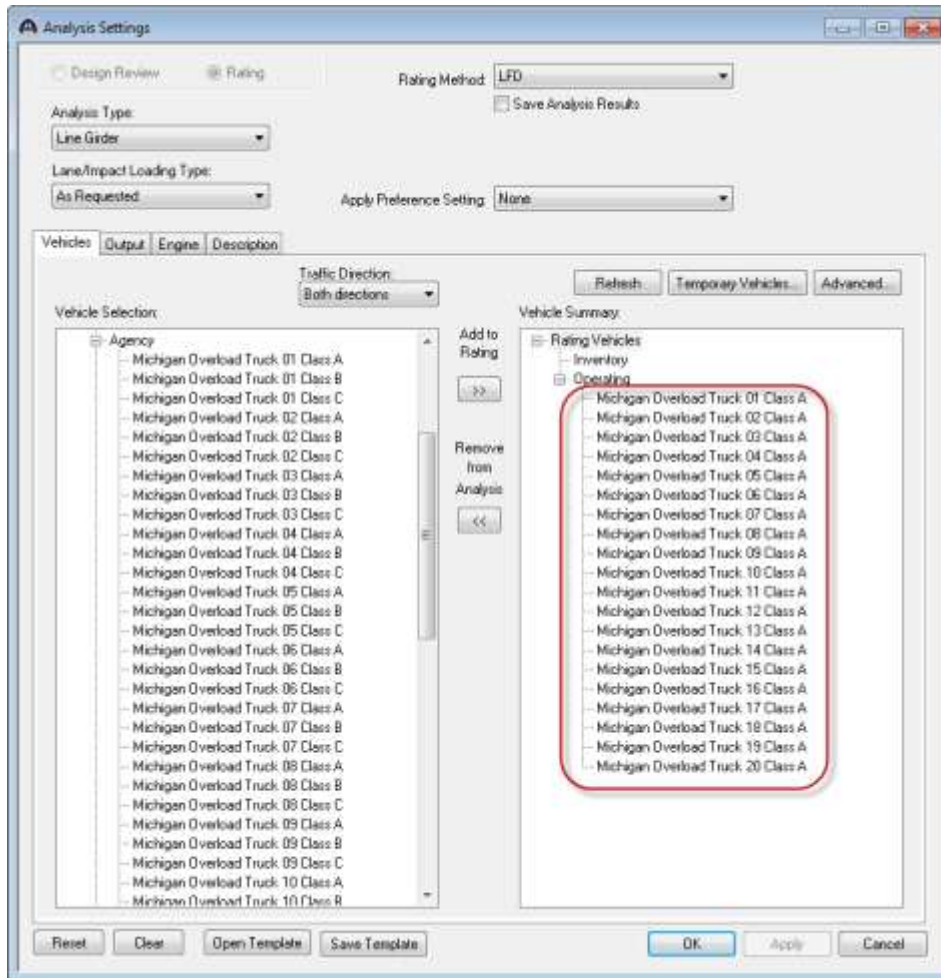


Figure 92. Entering the 20 Class A Michigan overload vehicles in Virtis

Member Rating Results

System of Units: US Customary SI / Metric

Lane/Impact Loading Type: As Requested Detailed

Display Format: Multiple rating levels per row

Bridge ID	Structure	Member	Vehicle	Inventory Rating Factor	Operating Rating Factor	Legal Rating Factor	Permit Rating Factor	Inven. Cost (To)
191190430005020	Span 1 thru 5	G6	Michigan Overload Truck 16 Class A		0.650			
191190430005020	Span 1 thru 5	G6	Michigan Overload Truck 16 Class A		0.684			
191190430005020	Span 1 thru 5	G6	Michigan Overload Truck 15 Class A		0.651			
191190430005020	Span 1 thru 5	G6	Michigan Overload Truck 16 Class A		0.694			
191190430005020	Span 1 thru 5	G4	Michigan Overload Truck 16 Class A		0.698			
191190430005020	Span 1 thru 5	G6	Michigan Overload Truck 17 Class A		0.699			
191190430005020	Span 1 thru 5	G5	Michigan Overload Truck 16 Class A		0.699			
191190430005020	Span 1 thru 5	G4	Michigan Overload Truck 18 Class A		0.761			
191190430005020	Span 1 thru 5	G5	Michigan Overload Truck 15 Class A		0.703			
191190430005020	Span 1 thru 5	G2	Michigan Overload Truck 16 Class A		0.704			
191190430005020	Span 1 thru 5	G4	Michigan Overload Truck 15 Class A		0.705			
191190430005020	Span 1 thru 5	G5	Michigan Overload Truck 17 Class A		0.768			
191190430005020	Span 1 thru 5	G2	Michigan Overload Truck 18 Class A		0.708			
191190430005020	Span 1 thru 5	G6	Michigan Overload Truck 20 Class A		0.709			
191190430005020	Span 1 thru 5	G4	Michigan Overload Truck 17 Class A		0.710			
191190430005020	Span 1 thru 5	G2	Michigan Overload Truck 15 Class A		0.711			
191190430005020	Span 1 thru 5	G2	Michigan Overload Truck 17 Class A		0.717			
191190430005020	Span 1 thru 5	G6	Michigan Overload Truck 19 Class A		0.722			
191190430005020	Span 1 thru 5	G5	Michigan Overload Truck 14 Class A		0.757			

Show up-to-date results only

Print Close

Figure 93. Reviewing the rating results in Virtis

Based on the rating results, it is evident that girder G6 governs for this bridge. This means that G1, G2, G3, G4, and G5 can be turned off by unchecking the 'Existing' checkbox on each girder (see Figure 94)

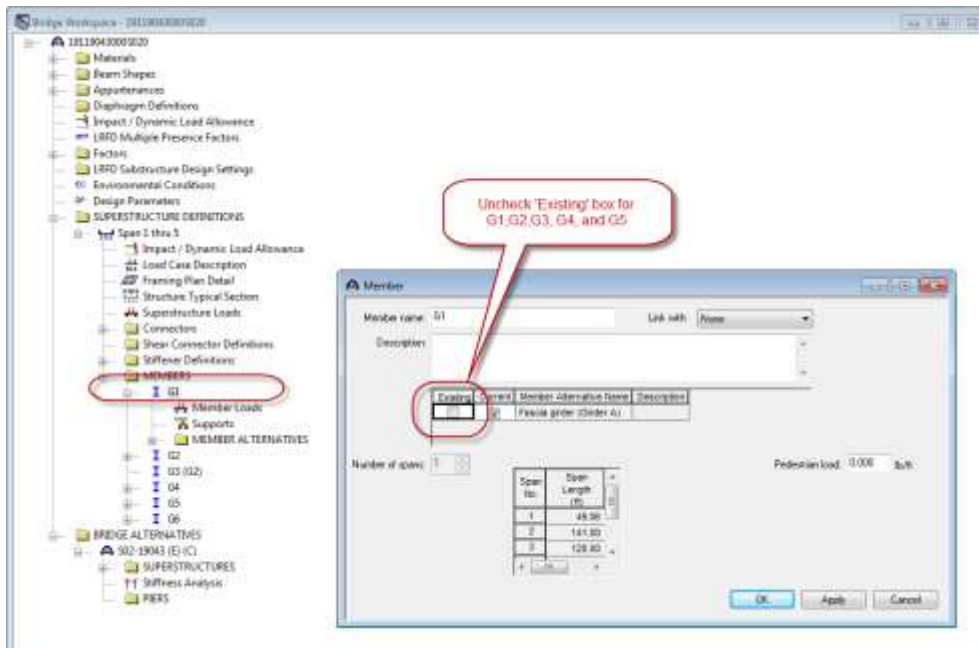


Figure 94. Turning of the 'Existing' flag in Virtis

The final run time for the same 3 axle vehicle while running Virtis through BridgeOv-Virtis is 0 min and 55 sec. Performing this task for all bridges in the set yielded a total time of 32 min and 9 sec (see Figure 95).

```

Processing Bridge #1-'63163192000S010' (Time: 0 hours, 1 min, 49 sec)
Processing Bridge #2-'82182023000S270' (Time: 0 hours, 0 min, 52 sec)
Processing Bridge #3-'82182192000S040' (Time: 0 hours, 0 min, 38 sec)
Processing Bridge #4-'41141064000R020' (Time: 0 hours, 0 min, 11 sec)
Processing Bridge #5-'63163111000R020' (Time: 0 hours, 0 min, 36 sec)
Processing Bridge #6-'19119033000S090' (Time: 0 hours, 0 min, 23 sec)
Processing Bridge #7-'11111016000B013' (Time: 0 hours, 3 min, 25 sec)
Processing Bridge #8-'23123063000S130' (Time: 0 hours, 0 min, 26 sec)
Processing Bridge #9-'82182022000S430' (Time: 0 hours, 0 min, 16 sec)
Processing Bridge #10-'49149025000S050' (Time: 0 hours, 0 min, 26 sec)
Processing Bridge #11-'38138101000S100' (Time: 0 hours, 0 min, 2 sec)
Processing Bridge #12-'50150062000S110' (Time: 0 hours, 0 min, 49 sec)
Processing Bridge #13-'63163191000S010' (Time: 0 hours, 0 min, 38 sec)
Processing Bridge #14-'82182081000S061' (Time: 0 hours, 0 min, 23 sec)
Processing Bridge #15-'50150061000S030' (Time: 0 hours, 0 min, 55 sec)
Processing Bridge #16-'50150061000S140' (Time: 0 hours, 2 min, 54 sec)
Processing Bridge #17-'82182291000B020' (Time: 0 hours, 0 min, 5 sec)
Processing Bridge #18-'63163191000S100' (Time: 0 hours, 1 min, 2 sec)
Processing Bridge #19-'19119043000S020' (Time: 0 hours, 0 min, 55 sec)
Processing Bridge #20-'25125031000S110' (Time: 0 hours, 0 min, 20 sec)
Processing Bridge #21-'58158151000S100' (Time: 0 hours, 3 min, 39 sec)
Processing Bridge #22-'25125132000S230' (Time: 0 hours, 3 min, 39 sec)
Processing Bridge #23-'50150111000S274' (Time: 0 hours, 0 min, 42 sec)
Processing Bridge #24-'82182022000S480' (Time: 0 hours, 0 min, 12 sec)
Processing Bridge #25-'82182022000S420' (Time: 0 hours, 0 min, 39 sec)
Processing Bridge #26-'13113033000B010' (Time: 0 hours, 0 min, 5 sec)
Processing Bridge #27-'82182191000S240' (Time: 0 hours, 1 min, 23 sec)
Processing Bridge #28-'41141027000B020' (Time: 0 hours, 1 min, 52 sec)
Processing Bridge #29-'41141027000B020' (Time: 0 hours, 2 min, 37 sec)
Processing Bridge #30-'a41141064000R020' (Time: 0 hours, 0 min, 0 sec)
Processing Bridge #31-'b41141064000R020' (Time: 0 hours, 0 min, 0 sec)
Processing Bridge #32-'c41141064000R020' (Time: 0 hours, 0 min, 0 sec)
(Total Time: 0 hours, 32 min, 9 sec)

```

Figure 95. Results after revision of 'Existing' flag in Virtis

10.3 BridgeOV-Standalone

This section describes the option to run BridgeOV-Standalone by using a BridgeOV input file directly. Also described is the method to run BridgeOV-Standalone in tandem with the BridgeOV-Virtis interface.

10.3.1 Running the BridgeOV-Standalone Program

This section provides a tutorial for running the BridgeOV-Standalone program.

10.3.1.1 Getting Started

To open a BridgeOV-Standalone window, click on the 'Tools' menu and select 'BridgeOV-Standalone' (see Figure 96).

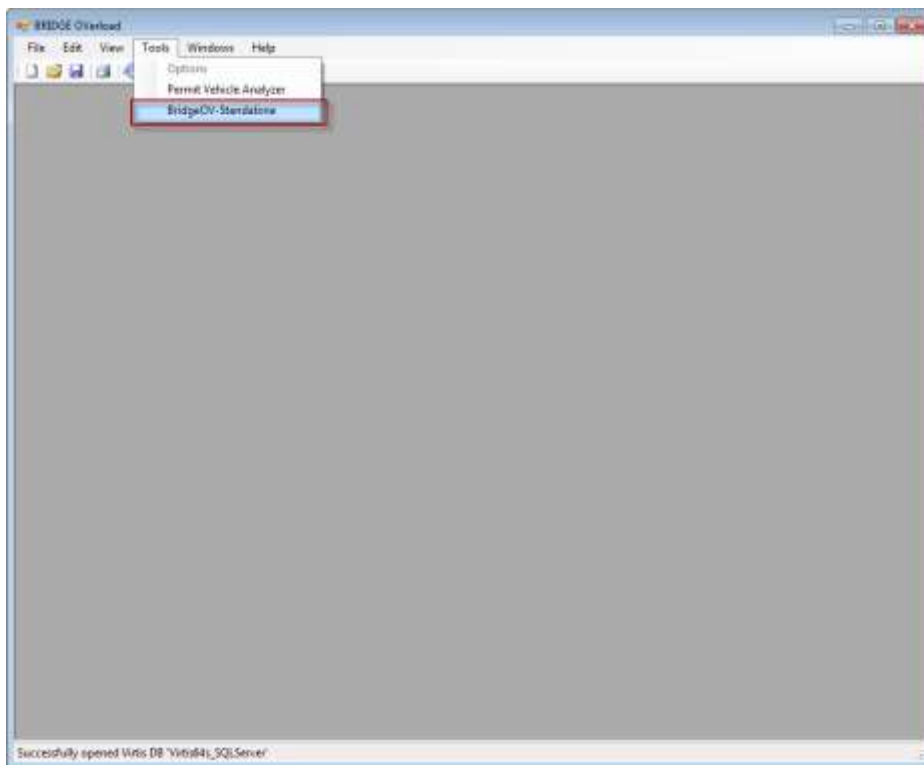


Figure 96. Opening a BridgeOV-Standalone window

Browse to a directory with BridgeOV input files and select one or more files (see Figure 97). These files have a .TXT extension and have a format as described in Section 10.3.2.

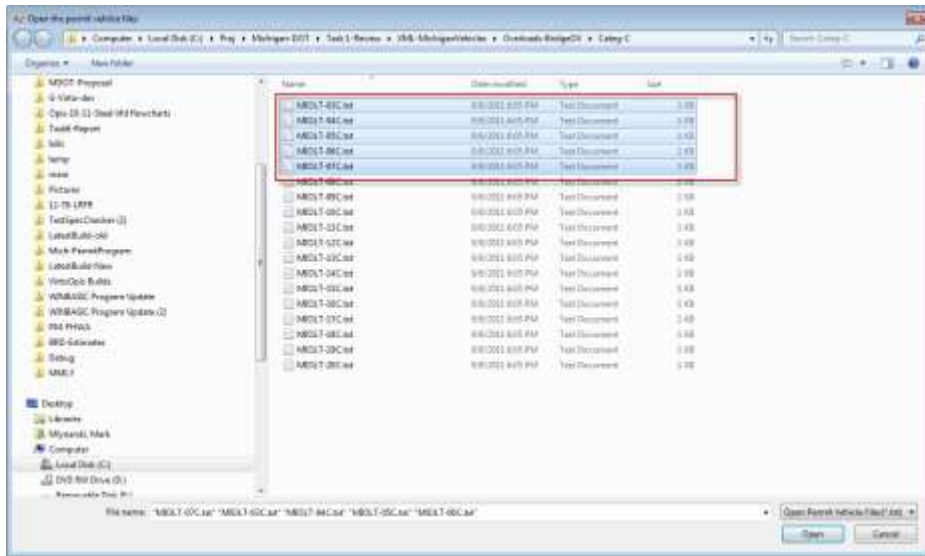


Figure 97. Opening multiple BridgeOV standalone files

This will open the main BridgeOV-Standalone interface and plot all of the input files in BridgeOV on the same graph.

10.3.1.2 Interface Options

This section provides a description of the various options available in the BridgeOV-Standalone interface. Figure 98 provides the layout for the interface.

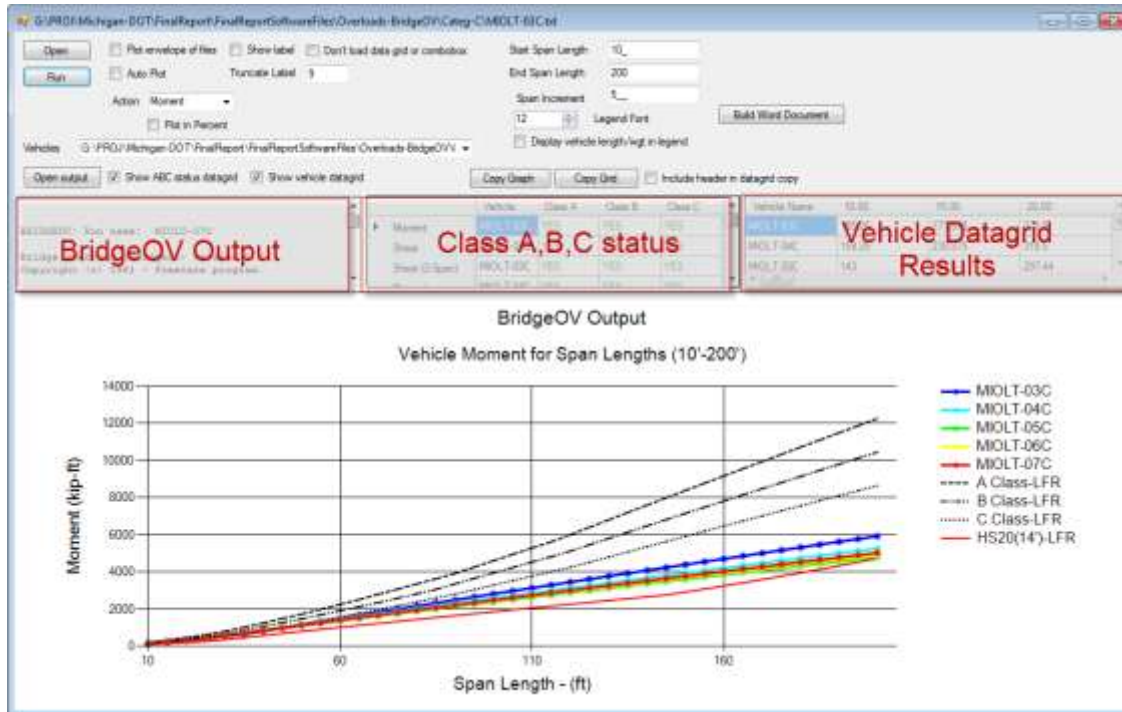


Figure 98. BridgeOV standalone interface

Open

Opens one or more BridgeOV vehicles files.

Run

Runs the file shown in the 'File List' in BridgeOV and plots together

Plot envelope of files

If multiple vehicles are loaded into BridgeOV, the envelope (or single series) will plot when this box is checked. If this is not checked, the individual vehicles will be plotted as separate series on the same graph.

Show label

Checking this box will label each point with the vehicle description. This box is only applicable when plotting an envelope of the files.

Truncate label

This field provides an option to control the length of the label when labeling the graph. Invalid entries will default the number to the length of the vehicle string. The number will default to '4' if a lesser number is entered.

Auto plot

Checking this box will cause the graph to update as input is changed on this screen. If the box is unchecked, the user must click the 'Run' button to replot the graph. If large numbers of vehicles are input, it is typically best to uncheck this box as the response time will be slower.

Vehicles Selection pulldown

Selects an individual file from the pulldown box, runs BridgeOV and plots. This pulldown lists the BridgeOV output for each vehicle loaded. The output file for each vehicle can be reviewed individually in the BridgeOV output window (see Figure 98) by selecting a file in this pulldown.

Don't Load data grid or combo box

Checking this box, prevents the data grid or the combo box from being loaded. If a larger number of vehicles is loaded into BridgeOV (e.g. more than 30) and a small span increment is used, the loading of these portions of the window can take a very long time. Sometimes it is better to turn these off until the data is set as desired.

Open output

Opens the output currently loaded in the 'BridgeOV output' box into a separate window.

Start Span Length

Span length to start BridgeOV.

End Span Length

Final span length to analyze/plot

Span Increment

Increment of span length to analyze/plot.

Action - Moment/Shear

Modify this box to plot either moment, shear, or 2-span shear.

Plot in percent

Check this box to plot the vehicles as a percent of the HS-20 (14' rear spacing) vehicle.

Legend Font

Changes the font size of the legend

Display vehicle length/wgt in legend

If checked, displays the vehicle length/weight as part of the legend title. If not checked, legend displays only the vehicle name.

Build Word Document

This feature requires that a blank MS-Word document 'BridgeOVTemplate.docx' is present on your c: drive in the Virtis installation directory (the typically is named C:\Program Files (x86)\AASHTOWARE\VirtisOpis64). If the file is present, clicking this button will plot all vehicles currently loaded and insert a copy of each graph into the Word document. It is recommended that once generated, the BridgeOVTemplate.docx file be saved as another filename so that the BridgeOVTemplate.docx file remains blank.

Open output

Displays the BridgeOV output in a text window. The output displayed, corresponds to the vehicle selected in the vehicle pulldown selection.

Show ABC status datagrid

Checking this box will display the class A,B,C status in a datagrid (see Figure 98). Unchecking the box will hide this datagrid.

Show vehicle datagrid

Checking this box will display the vehicle datagrid results (see Figure 98). Unchecking the box will hide this datagrid.

Vehicle Datagrid Results

The vehicle datagrid results only appear if the 'Show vehicle datagrid' checkbox is checked. The datagrid displays a copy of the analysis results by span length for each vehicle plotted. This data can be copied to the clipboard using the 'Copy Grid' command and pasted directly in an Excel spreadsheet.

Copy Graph

Copies the current graph to the clipboard

Copy Grid

Copies the current data grid to the clipboard. Once copied to the clipboard, the contents can easily be pasted into an Excel spreadsheet by using the past command while in Excel. Once pasted, the user can use formatting in Excel to manipulate the data.

Include header in copy

If checked, will include the data grid header when copying the data grid to the clipboard.

10.3.2 Running BridgeOV-Standalone using BridgeOV-Virtis

BridgeOV-Standalone may be run using BridgeOV input files created using a text editor such as Notepad or WordPad (see Section 10.3.3 for the file format), or by using the BridgeOV-Virtis interface. With this interface, the user can interactively create a new file and vehicle and run BridgeOV repeatedly. To do this, follow the steps below.

Step 1 – Create a ‘New’ BridgeOv-Virtis input (see Figure 99).

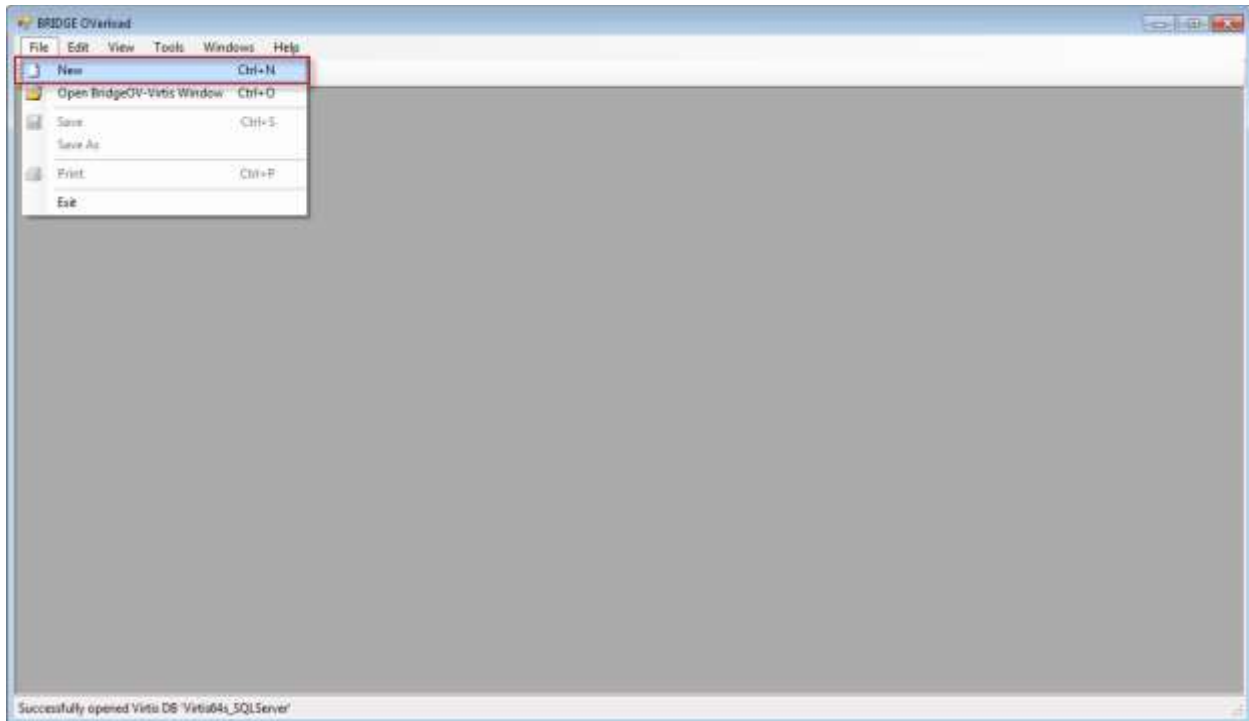


Figure 99. Creating a ‘New’ BridgeOV-Virtis file

Step 2 – The default for the new file will contain 1 bridge with the Bridge ID of ‘BridgeID’ (see Figure 100) and a three-axle vehicle as shown in Figure 101. The user can either modify this vehicle by adding more axles (using the ‘Add Row’ button), deleting axles (using the ‘Delete Row’ button) and modifying the axle weights, and axle spacings.

The single bridge ‘BridgeID’ does not need to be modified. This bridge should not appear in the Virtis database so when the ‘Run Virtis/BridgeOV’ button is selected, the bridge will not be found in the Virtis DB and results for BridgeOV will be returned. If a bridge with this name happens to be in the Virtis DB, the name (‘BridgeID’) will need to be modified to something that does not exist in the Virtis DB.

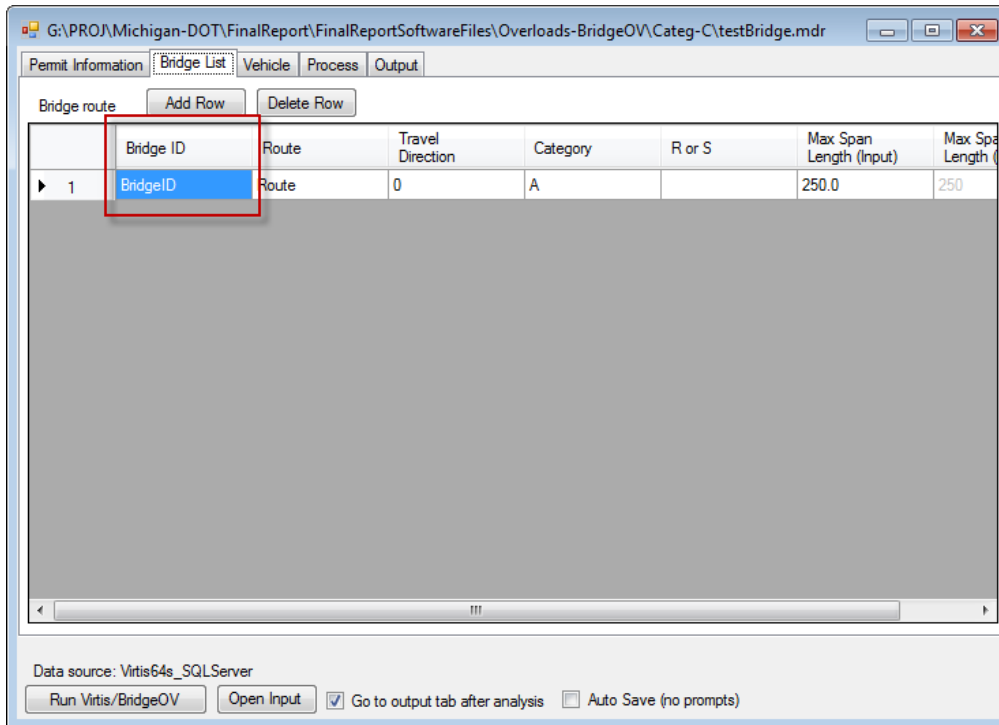


Figure 100. Default 'Bridge ID' for a new input file in BridgeOV-Virtis

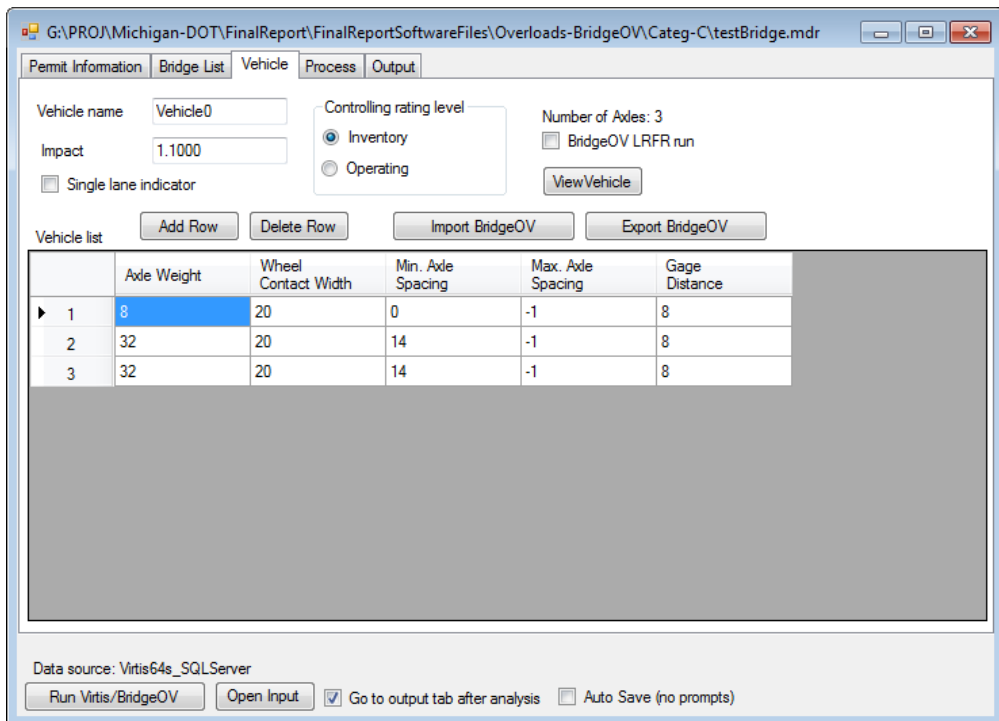


Figure 101. Default vehicle configuration for a new BridgeOV-Virtis input file.

Step 3 – Click on the ‘Run Virtis/BridgeOV’ button. The program should run very quickly and automatically move to the ‘Output’ tab when completed. Now click on the ‘BridgeOV Plot’ button to open BridgeOV-Standalone (see Figure 102). This will display both windows within the interface; BridgeOV-Virtis on the left and BridgeOV-Standalone on the right (see Figure 103).

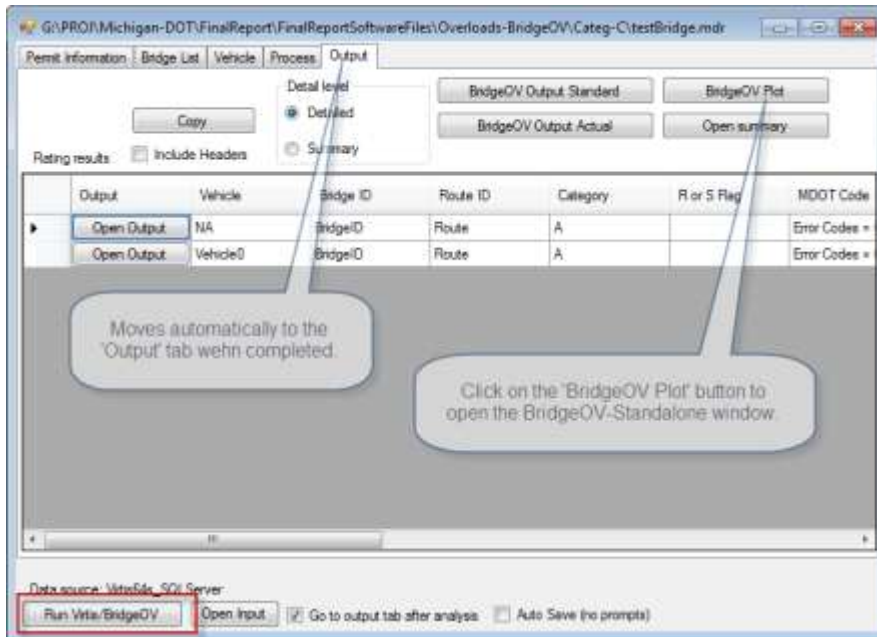


Figure 102. Steps to plot BridgeOV-Standalone from BridgeOV-Virtis

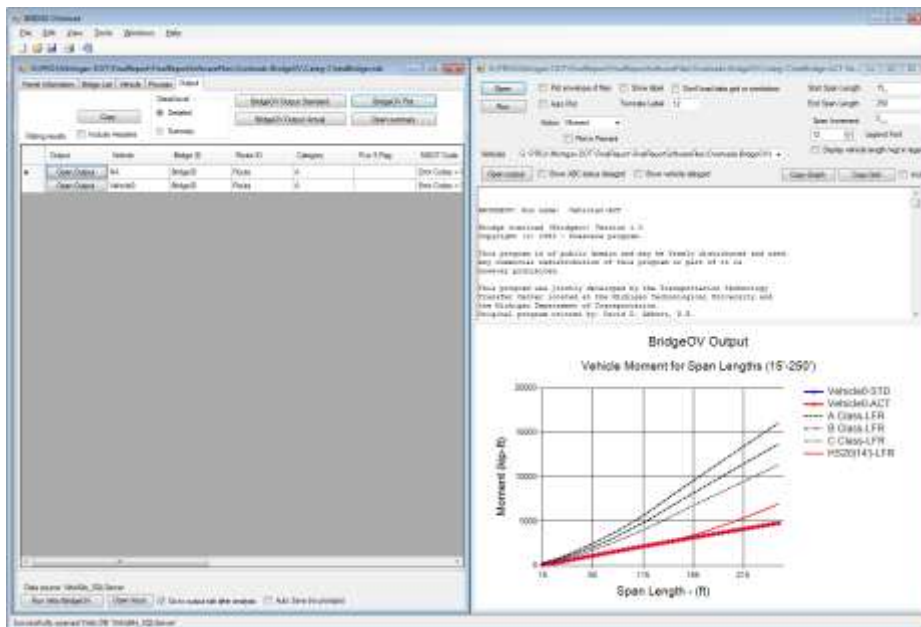


Figure 103. BridgeOV-Virtis and BridgeOV-Standalone

Step 4 – Now go to the ‘Vehicle’ tab of the BridgeOV-Virtis window and uncheck the ‘Go to output tab after analysis’. Also check the ‘Auto Save (no prompts)’ checkbox (see Figure 104). Modify the vehicle by adding axles or changing the weights/spacings, etc. Now click the ‘Run Virtis/BridgeOV’ button. The graph and output in the BridgeOV-Standalone window will automatically update.

Once the vehicle is defined, it can be saved by either using the ‘Export BridgeOV’ button, or saving the BridgeOV-Virtis input file.

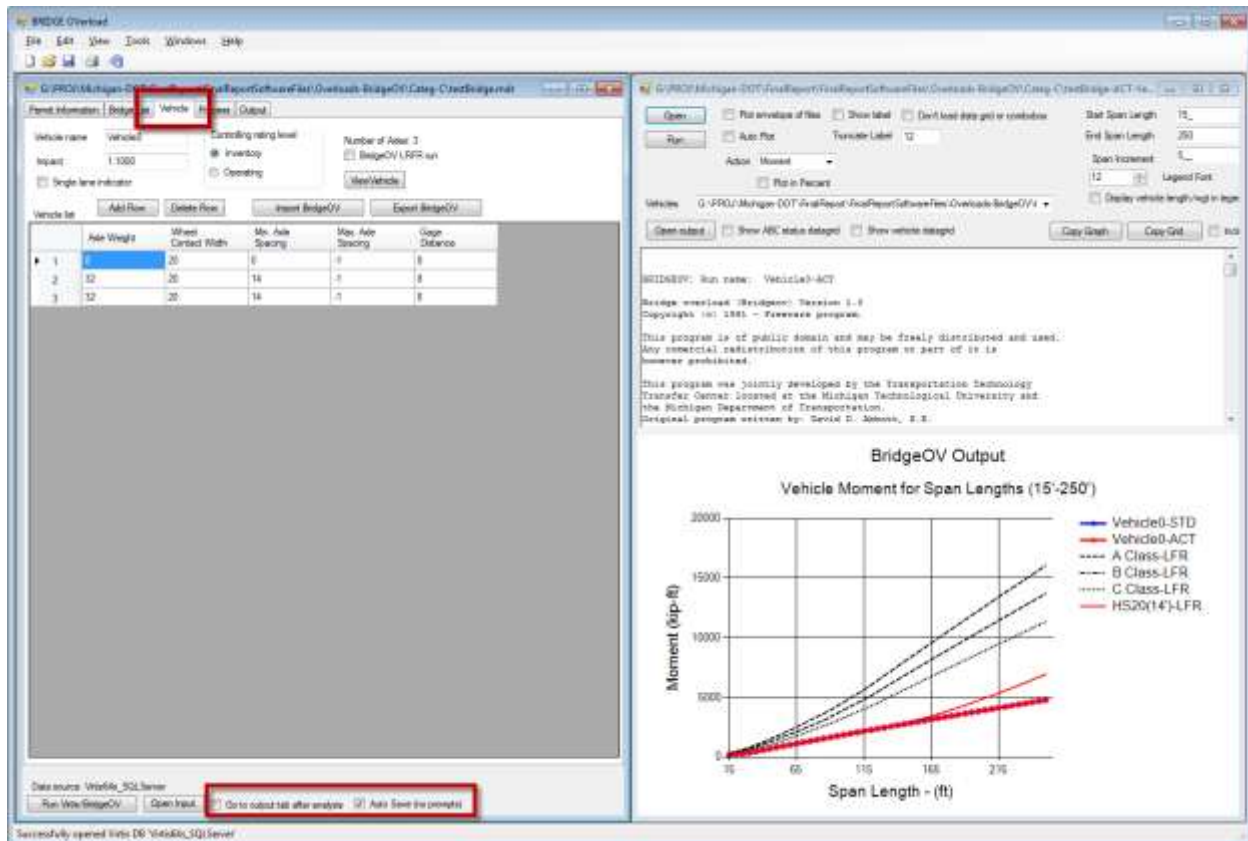


Figure 104. Setting parameters for BridgeOV-Virtis to run in tandem with BridgeOV-Standalone

10.3.3 BridgeOV input file

The BridgeOV input file is relatively simple and has a format as shown in Figure 105.

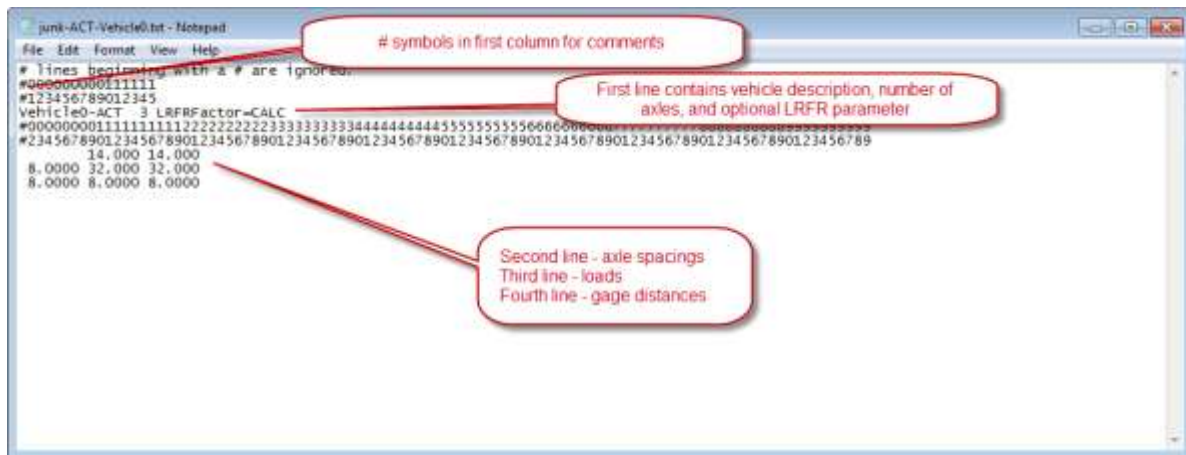


Figure 105. BridgeOV input format

Comment lines

All lines at the beginning of the file with the '#' symbol in the first column are ignored by the software. These can be used for placing comments.

First line

This line can contain 3 parameters (the third parameter is optional) and all parameters must be separated by a space.

Parameter	Description
1	Contains the description of the vehicle. This must contain no spaces.
2	Number of axles (required)
3	<p>This parameter is optional. If not entered, a live load factor of 1.0 will be used along with an LFR impact factor.</p> <p>If entered, It can contain the following input: LRFRFactor=CALC or LRFRFactor=x.x</p> <p>The parameter should have no spaces. If 'CALC' is used, the program will calculate the LRFR live load factor based on the Curtis/ Till Equation 18 (see Section 5.1.8 of this document).</p> <p>If a value is input, the live load factor will be set to the value entered.</p>

Second line

Enter axle spacings in feet for the vehicle separated by spaces. The number of values input must be the Number of Axles – 1.

Third line

Enter axle loads in kips for each axle separated by spaces. The number of values input must be the equal to the Number of Axles input on the first line.

Fourth line

Enter axle gage distances in feet for each axle separated by spaces. The number of values input must be the equal to the Number of Axles input on the first line. Each axle will be factored by $1 / (\text{Gage} + 8) / 16$. If the value is equal to 8.0, the factor is 1.0. If the value input is less than 8, it will be set equal to 8.0. If the value is greater than 8.0, it has the effect of reducing the axle weight.

10.3.4 BridgeOV output file

The BridgeOV output is fairly self-explanatory. In addition to an echo of the input, tables are provided for simple span moment comparison, simple span shear comparison, and 2 equal span shear comparison. Figure 106 provides a diagram of the moment table comparisons for BridgeOV. The Shear tables are similar in layout. A separate BridgeOV output is generated for each vehicle and they can be viewed individually using the 'Vehicles Selection pulldown' and 'Open output' button as described in Section 10.3.1.2.

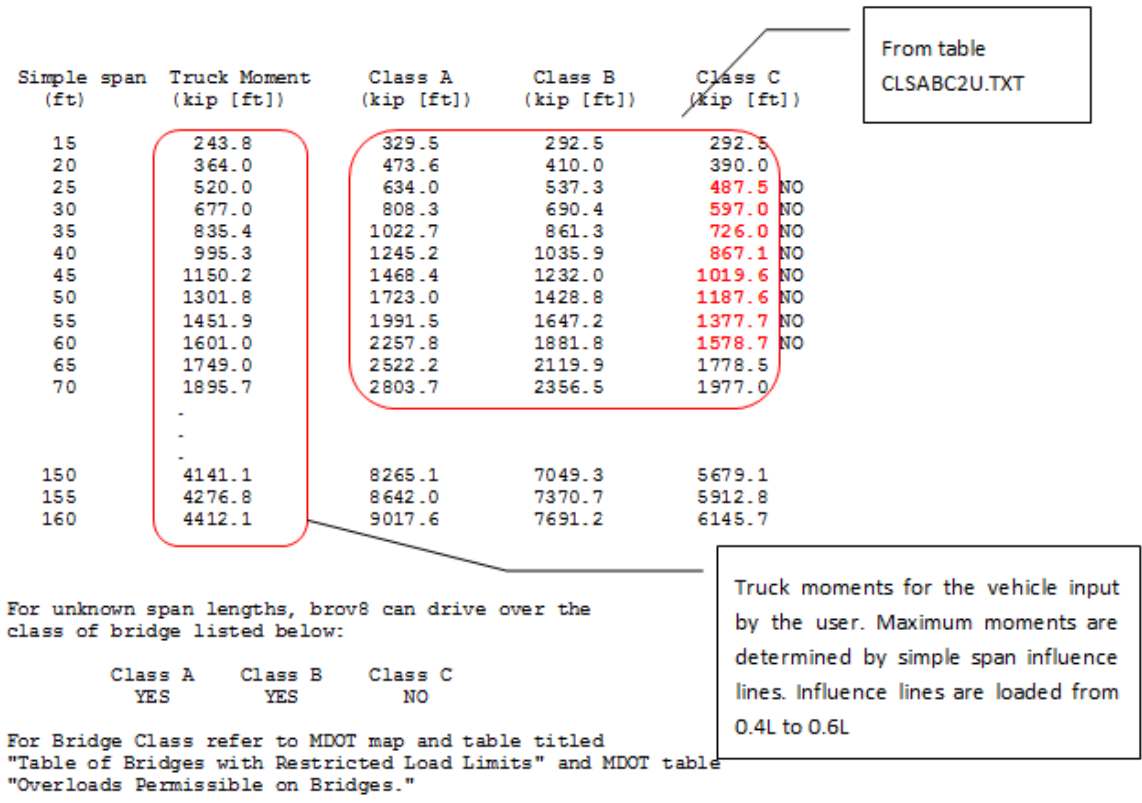


Figure 106. BridgeOV moment output description

10.4 Permit Vehicle Analyzer

The permit vehicle analyzer (PVA) is a tool available from the 'Tools' menu of BridgeOV Overload (see Figure 107).

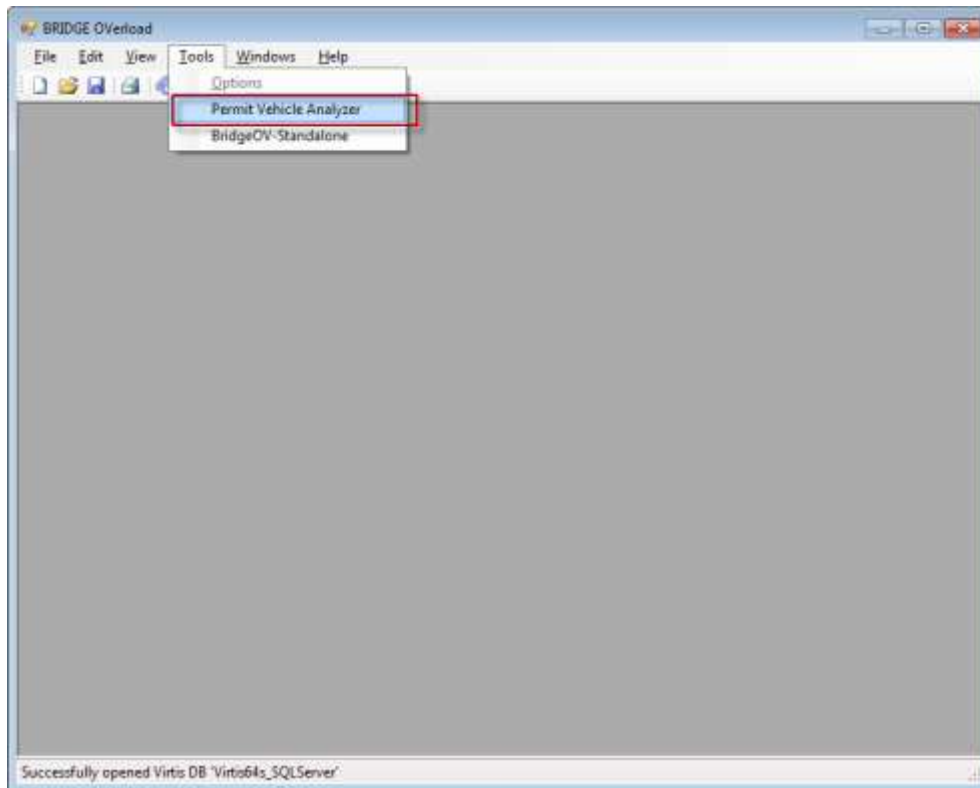


Figure 107. Opening the permit analyzer

The program reads in a large list of permit vehicles and provides the following features:

- Sorting out exact duplicate vehicles (same axle loads and spacings).
- Sorting vehicles by the highest 2,3,4 and 5 axle combinations.
- Searching for anomalies in the data (small axle spacings, loads, etc.)
- Generating Virtis and BridgeOV input files

The tool was used to research the heaviest of permit vehicles from a 1 year sample of MDOT vehicles and is provide here as a tool so that it may continue to be used in the future. A sample permit vehicle CSV file is also provided with the delivery.

The program also has the capability to read in Weigh-in-Motion data (WIM) in a format as described in Appendix H – Weigh-in-Motion – (WIM) file format. To read this type of data into PVA, select WIM from the file type pulldown when starting up PVA (see Figure 108).

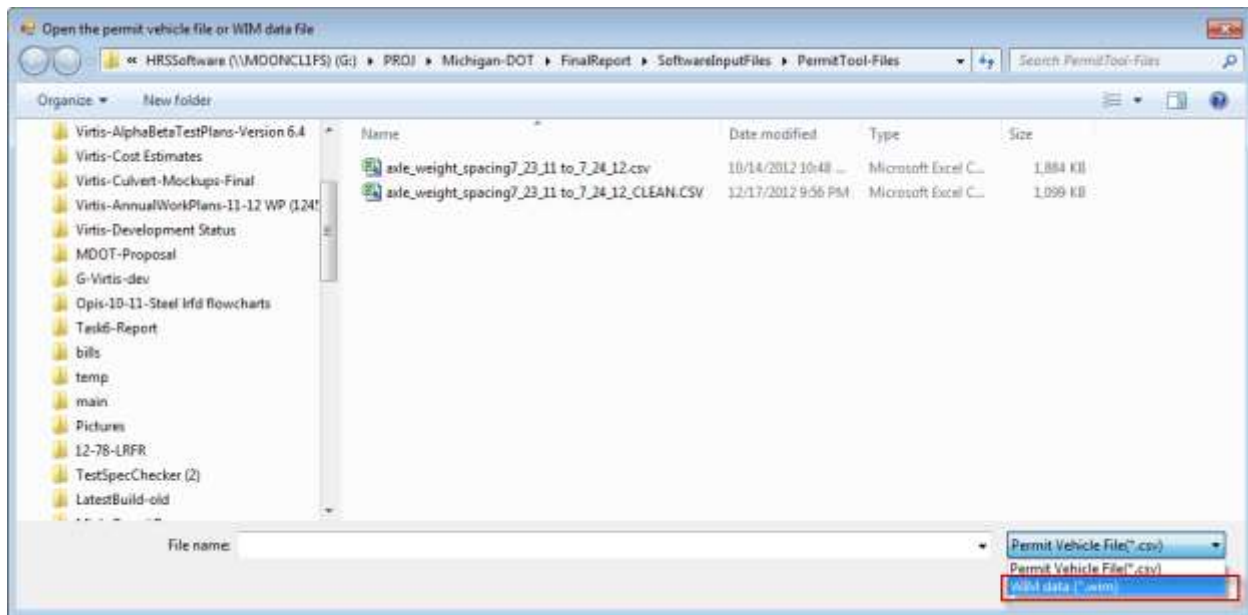


Figure 108. Opening WIM data in PVA

10.4.1 Preparing an MDOT Excel file

Before the spreadsheet provided by the permits department can be used by the analyzer, the following steps must be followed to convert the spreadsheet to a CSV file that can be used by the program.

- Make all of the rows the same height (this shows the blank lines between each record). Highlight all of the cells and set the row height
- Unmerge all cells. Keep all cells selected and change the format as shown in Figure 109 below.

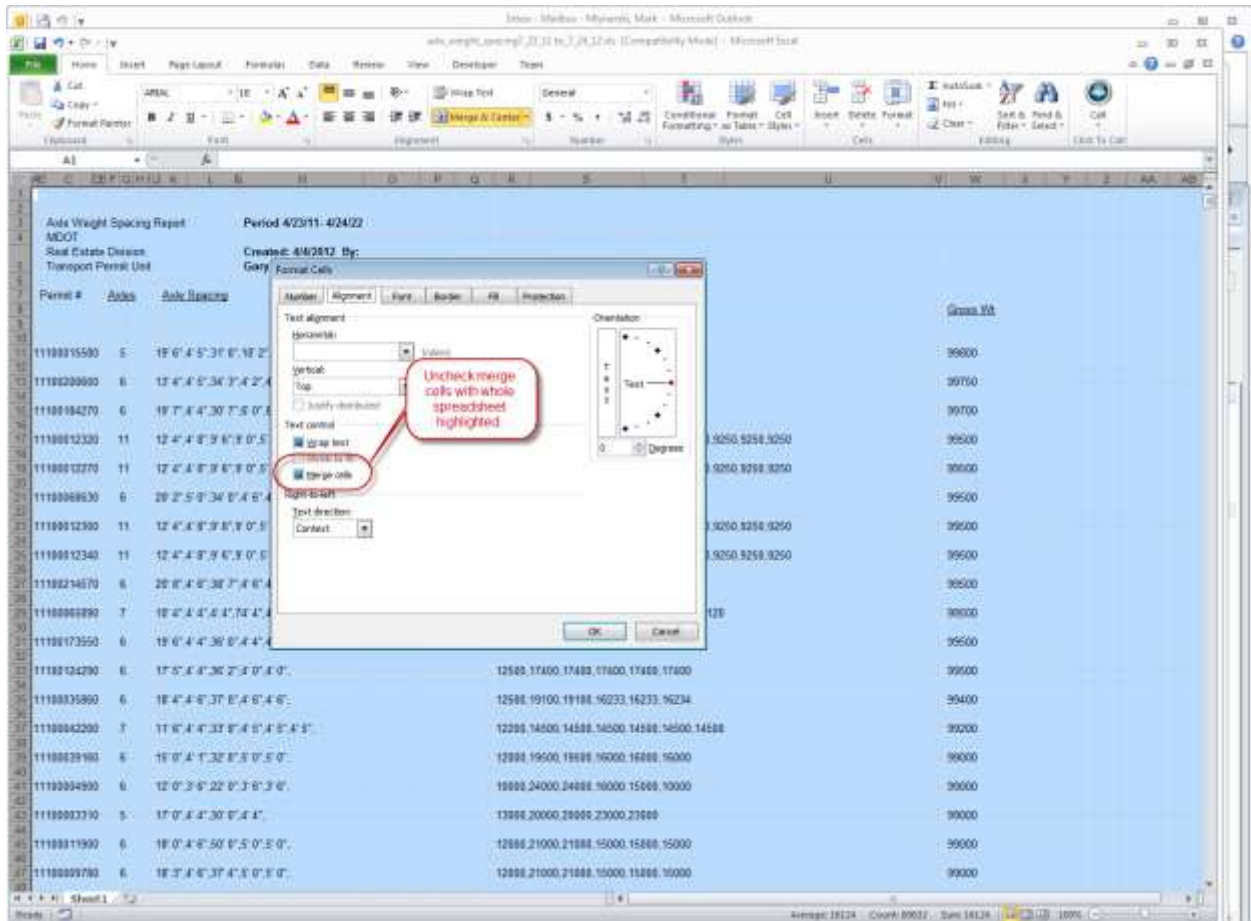


Figure 109. Turning off 'Merge cells' in a permit vehicle Excel spreadsheet

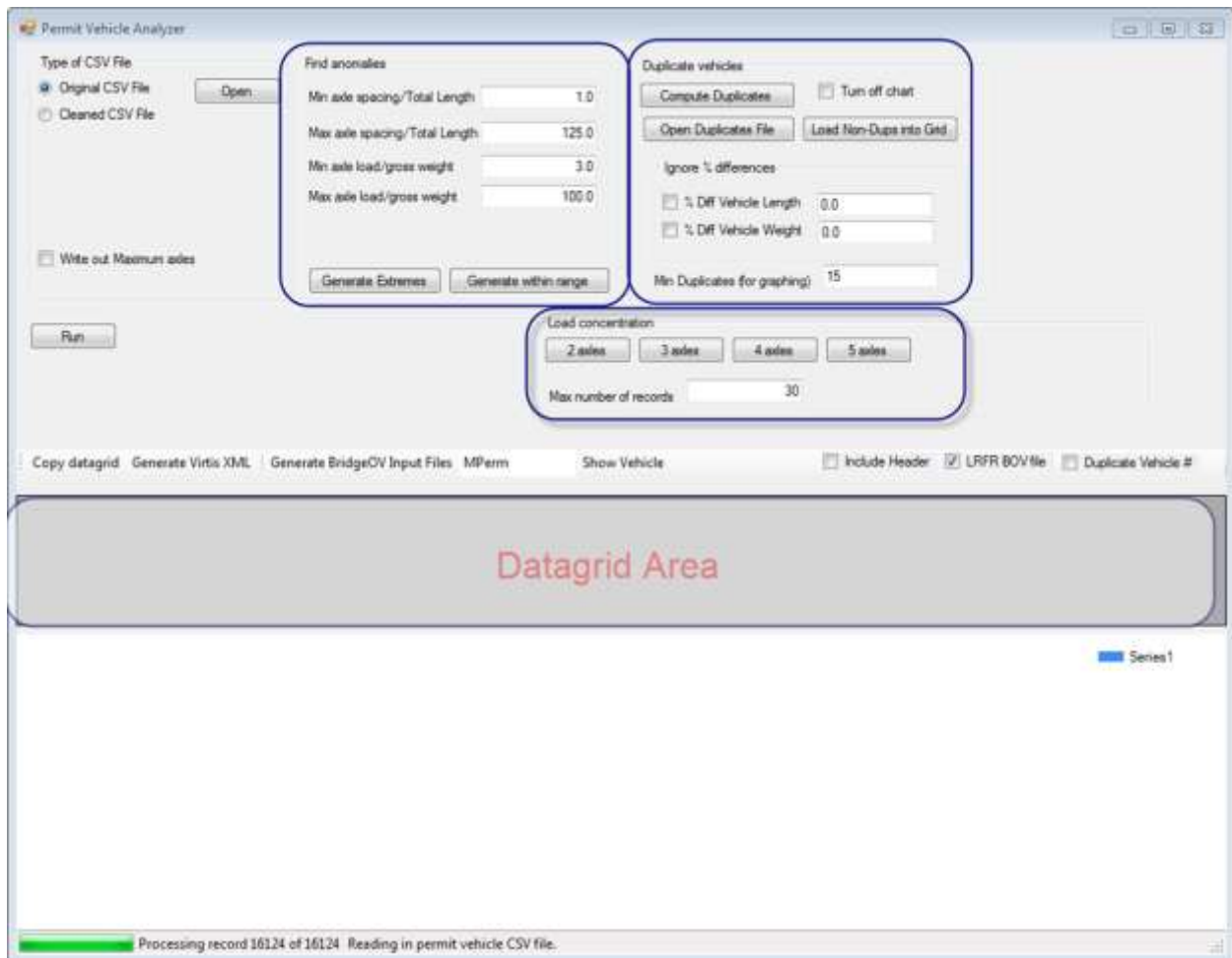


Figure 111. Permit Vehicle Analyzer screen

Some highlights of the analyzer are:

Find anomalies

This section allows the user to search the list of vehicles for small (or large) axle spacings and loadings. Clicking the 'Generate Extremes' button will search the vehicles loaded for the extremes specified. The list of vehicles found will appear in the datagrid area and can be copied elsewhere (e.g. to a spreadsheet).

Duplicate vehicles

This section allows the user to search for exact duplicate vehicles. The results are plotted in the graphing area (see Figure 112).

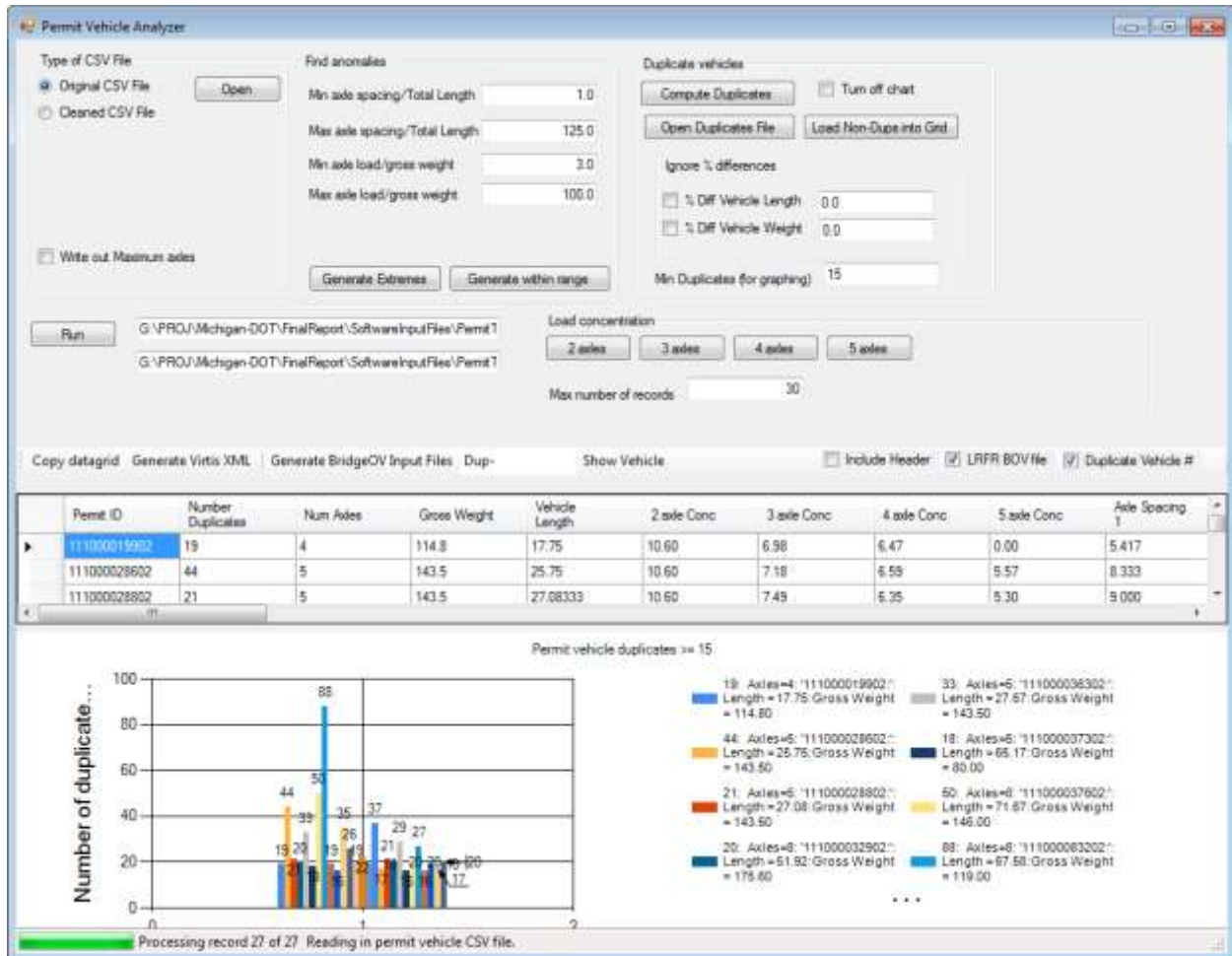


Figure 112. Graphing duplicate vehicles

Load Concentration

This section allows the user to sort vehicles by load concentration. This tool was used to generate the axle concentration lists as describe in Section 5.1.4. The list of the largest axle concentrations are placed in the datagrid area for copying into the clipboard.

Datagrid Area

For the above operations, the vehicles are copied to the ‘DataGrid Area’. Once vehicles are placed here, they can also be exported as BridgeOV files and run in the standalone version of BridgeOV. The options for the data grid are as follows:

Copy datagrid

Copies the highlighted datagrid to the clipboard. Only the highlighted rows will be copied to the clipboard. If the ‘Include Header’ option is checked, the headings will

be copied to the clipboards as well. Once copied, the vehicles can be pasted directly into a spreadsheet.

Generate Virtis XML

Will generate Virtis XML files for each row of the datagrid that is selected. The Virtis XML vehicle files can then be imported into the Virtis Vehicle library.

Generate BridgeOV input files

Will generate BridgeOV input files for each row of the datagrid that is selected. The BridgeOV input files can then be opened in the BridgeOV-Standalone tool. If the 'LRFR BOV file' box is checked, LRFR BridgeOV input files are generated. The textbox next to the 'Generate BridgeOV Input Files' button contains the prefix for each vehicle name generated.

If the 'Duplicate Vehicle #' box is checked, the number of duplicates for the vehicle will be included in the vehicle name.

Show Vehicle

Clicking on the button will graphically display the vehicle in a separate window for the current datagrid row. If the graphic vehicle window is already open, the window will update as the datagrid row is changed.

11 List of Acronyms/Glossary

AASHTO - American Association of State Highway and Transportation Officials.

BridgeOV – Bridge overload software originally written by Michigan Tech and MDOT and updated for this research project. Analyzes vehicles for span lengths up to 250' for simple span moment, simple span shear, and 2 equal span shear.

Final Phase – the final phase of this research project where the recommendations for the interim phase were implemented.

Interim Phase – the first phase of this research project when the Michigan processes for overload vehicles were reviewed.

PVA–Permit vehicle analyzer – Software written for this research that reads in large files of permit vehicles (either CSV format or WIM format) and sorts them by weight, length, or axle concentration. Also determines the number of duplicate vehicles in the file.

Virtis – (Also known as BrR) – Bridge rating software produced by the American Association of State Highway and Transportation Officials (AASHTO). Michigan is current licensee and participant in the development of this software. During the development of this research project, the name of the AASHTOWare™ Virtis® software was changed by AASHTO to AASHTOWare™ Bridge Rating (BrR). The research report has retained the original name 'Virtis' throughout this report

WIM data – Weigh-in-Motion data- captured by WIM devices that are designed to capture and record axle weights and gross vehicle weights as vehicles drive over a measurement site.

12 References

Curtis, Rebecca and Till, Roger, (2008), *Recommendations for Michigan Specific Load and Resistance Factor Design Loads and Load and Resistance Factor Rating Procedures*, Research Report R-1511, Michigan Department of Transportation, Lansing, Michigan.

Michigan Department of Transportation (2005), *Bridge Analysis Guide*, Lansing, Michigan.

Appendix A – Excerpt from “SUPERLOAD Permitting and Routing Implementation”

Appendix A – Excerpt from “*SUPERLOAD Permitting and Routing Implementation*”

The following is an excerpt from the manual prepared by Bentley entitled “SUPERLOAD Permitting and Routing Implementation”.

4.2 MI-specific ABCD Bridge Analysis

For each bridge in the route network, the ABCD bridge classification code and the "R" (standard / non-standard gage / slab controls) code will be stored from the Pontis bridge inventory data (the ABCD_LOAD_CAPACITY and R_RATING fields respectively).

Generally, when a trip is to be analyzed for a permit vehicle, the configuration of the permit vehicle will be run through the "Bridge overload (Bridgeov) Version 1.0" program logic that was jointly developed by the Transportation Technology Transfer Center located at the Michigan Technological University and the Michigan Department of Transportation. It is a freeware program. This program calculates truck moments to determine whether the given truck should be allowed over bridges of various spans and classes. This logic will determine if the truck can cross A, B, and / or C class bridges. The route analysis will know the class of each bridge crossed over based on the bridge inventory data. The class of the bridge will be checked against the computations of whether or not the vehicle can cross that bridge class. Passing and failing analyses will be counted, summarized, and reported. A route analysis must pass all ABCD bridge checks to be successful.

The R code indicates that the main load carrying beams, girders or other members are spaced greater than 10-ft. For these bridges, the allowable axle loads cannot be adjusted for gage width. Whenever an "R" bridge is encountered, the truck must be evaluated for the actual axle loads, not the axle loads that were reduced to account for gage width. Reductions in loads based on axle widths are all computed in the MI process that evaluates the vehicle.

The R code field may also have an "S" value. If the field contains an S, it means that the slab controls. The R and S codes will be treated separately. As mentioned above, R bridges will not allow the adjustment of axle loads based on axle gage, while S bridges will. However, S bridges will be subject to an additional condition that B and C class bridges will not pass if any axle exceeds 38,000 pounds.

Following is the algorithm that will be used for all vehicle / bridge analysis, accounting for all ABCD and R/S codes.

1. Determine the A, B, C values for the actual permit vehicle configuration (inputting actual axle weights, spacings, and widths). Let's call the result of this step the 3 values - TruckA_ActualGage/AdjustedAxleWt, TruckB_ActualGage/AdjustedAxleWt, TruckC_ActualGage/AdjustedAxleWt, where each of these three values indicate whether or not the truck can pass each bridge type given the actual axle widths (reducing the axle weights as appropriate).
2. Determine the A, B, C values for the permit vehicle configuration BUT WITH STD 8' AXLE WIDTHS (inputting actual axle weights, spacings, and hardcoded 8' axle widths). Let's call the result of this step the 3 values - TruckA_StdGage/StdAxleWt, TruckB_StdGage/StdAxleWt, TruckC_StdGage/StdAxleWt, where each of these three values indicate whether or not the truck

Appendix A – Excerpt from “SUPERLOAD Permitting and Routing Implementation”

can pass each bridge type given the std gage, hardcoded 8' axle widths (using the standard / actual axle weight with no reduction allowed).

3. For each bridge, do the following evaluation....

- If the bridge has the R code, that specifies "the truck would have to be evaluated for the actual axle loads" - meaning the hardcoded std gage. Check the bridge classification against the "StdGage/StdAxleWt" Vehicle classification. For example, if it is a B + R bridge, see if the TruckB_StdGage/StdAxleWt indicates passing. If so, pass it. If not, fail it.

If the bridge DOES NOT have the R code, that specifies we should use "the axle loads that were reduced to account for gage width" - meaning the actual permit vehicle gage (which may or may not be std gage). Check the bridge classification against the "ActualGage/AdjustedAxleWt" Vehicle classification. For example, if it is an A bridge without the R, see if the TruckA_ActualGage/AdjustedAxleWt indicates passing. If so, pass it. If not, fail it. If the bridge passes, AND has the S code, AND is a B or C class bridge, also ensure no axle exceeds 38,000 pounds. If so, pass it. If not, fail it.

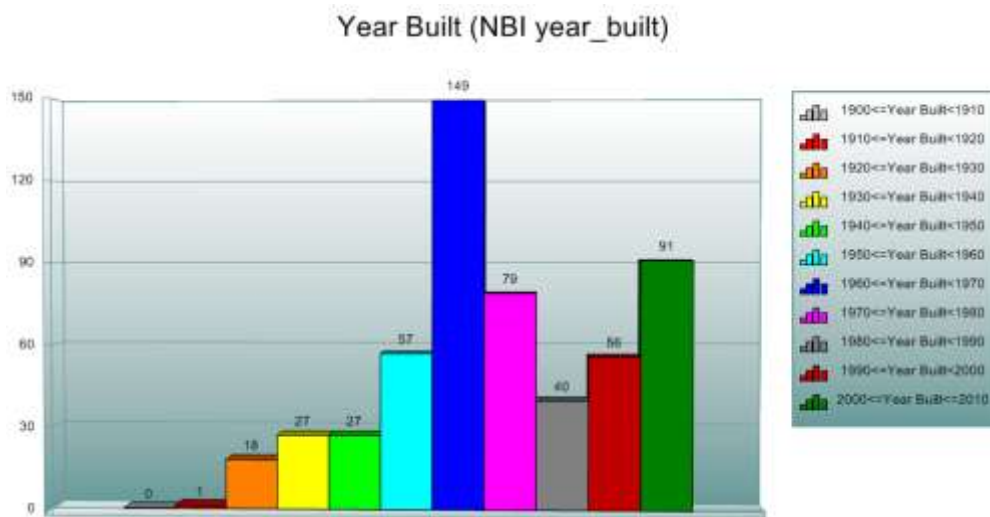
Appendix B – Michigan Virtis DB bridge demographics

Appendix B – Michigan Virtis DB bridge demographics

This appendix provides a breakdown of the 225 bridge Virtis database provided by MDOT for use on this project. The database was provided in the Interim Phase of the project and represents a portion of the total bridges that MDOT has input into Virtis. As of the date of this report, over 2000 bridges have been input into the MDOT Virtis database.

Year Built

The total breakdown of bridges by year built is shown below. The year built was extracted from the Virtis database and the break down seems to represent the typical nationwide breakdown from the NBI database.

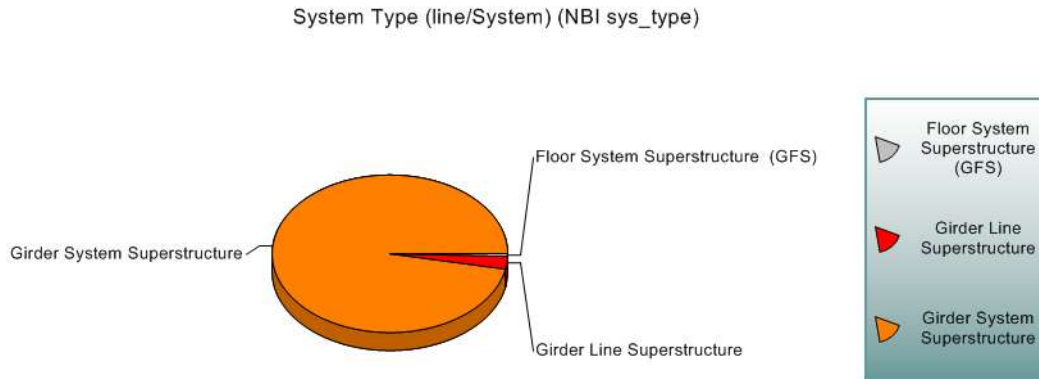


Year Built (NBI year_built)	Total	Percent %
1900<=Year Built<1910	0	0.00%
1910<=Year Built<1920	1	0.18%
1920<=Year Built<1930	18	3.30%
1930<=Year Built<1940	27	4.95%
1940<=Year Built<1950	27	4.95%
1950<=Year Built<1960	57	10.46%
1960<=Year Built<1970	149	27.34%
1970<=Year Built<1980	79	14.50%
1980<=Year Built<1990	40	7.34%
1990<=Year Built<2000	56	10.28%
2000<=Year Built<=2010	91	16.70%
Total	545	100.00%

Appendix B – Michigan Virtis DB bridge demographics

Structure Type

Virtis permits the input of structures in entire systems (i.e. all girders defined for the structure) or as a line superstructure (i.e. just the girder defined). The vast majority of structures received were 'Girder System Superstructures'. These are multi-girder systems. No trusses were in the database and just a few Girder-Floorbeam-Stringer bridges were included. See chart below for the distribution of bridge types.

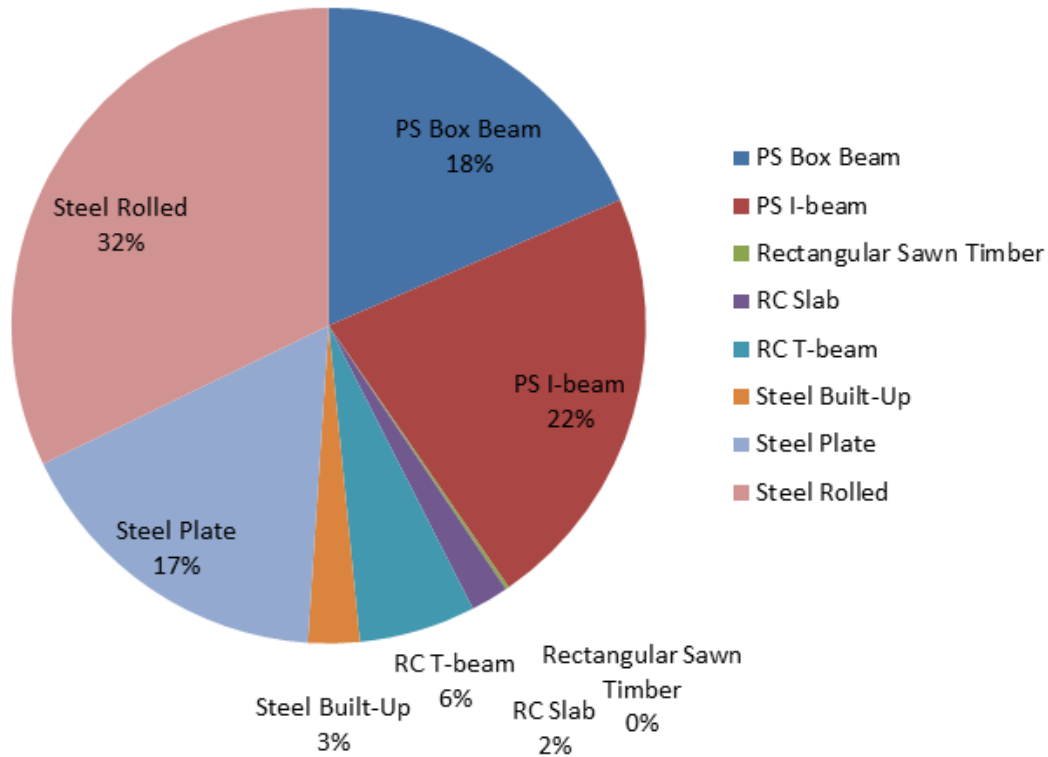


System Type (line/System) (NBI sys_type)	Total	Percent %
Floor System Superstructure (GFS)	3	0.55%
Girder Line Superstructure	14	2.57%
Girder System Superstructure	528	96.88%
Total	545	100.00%

Appendix B – Michigan Virtis DB bridge demographics

Material Type

The overall break down by structure type is as shown in the following table. Note that the total number (572) is greater than the total number of structures represented in the previous two charts. This is due to the fact that Virtis structures can be comprised of multiple types (e.g. you can have a structure that is comprised of steel main spans with PS approach spans).

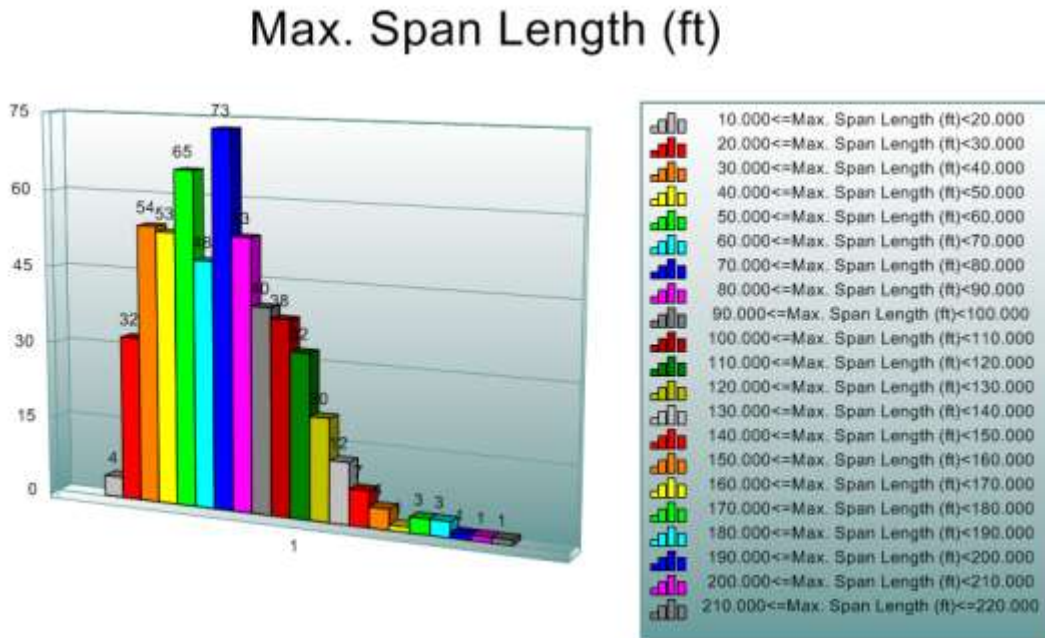


Type	# bridges	%
PS Box Beam	106	18.5%
PS I-beam	125	21.9%
PS T-beam	0	0.0%
PS U-beam	0	0.0%
Rectangular Sawn Timber	1	0.2%
RC I-beam	0	0.0%
RC Slab	11	1.9%
RC T-beam	34	5.9%
Steel Built-Up	15	2.6%
Steel Plate	96	16.8%
Steel Rolled	184	32.2%
Steel Truss	0	0.0%
Total	572	100.0%

Appendix B – Michigan Virtis DB bridge demographics

Span Length Breakdown

The following figure and chart represents the breakdown of the structures by span length. Note that none of the structure maximum span lengths exceeds 220’.

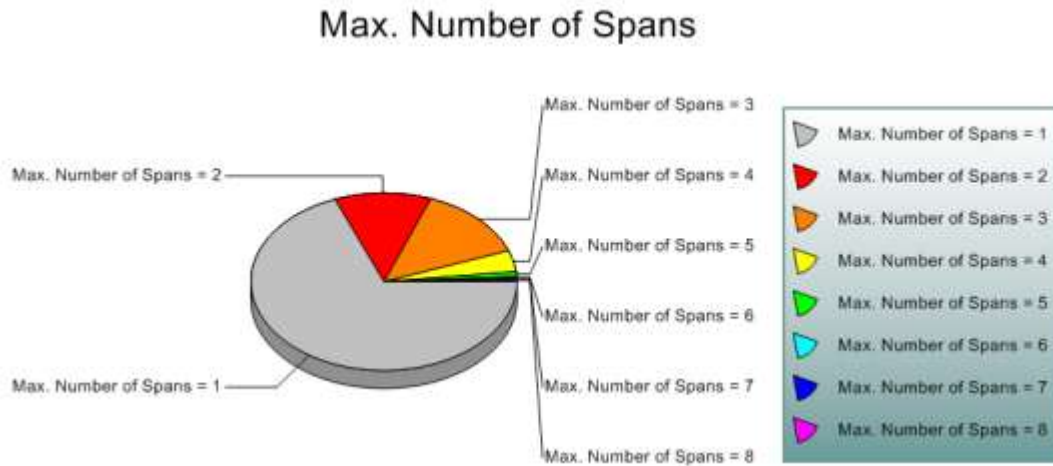


Max. Span Length (ft) (NBI max_span_length)	Total	Percent %
10.000<=Max. Span Length (ft)<20.000	4	0.73%
20.000<=Max. Span Length (ft)<30.000	32	5.87%
30.000<=Max. Span Length (ft)<40.000	54	9.91%
40.000<=Max. Span Length (ft)<50.000	53	9.72%
50.000<=Max. Span Length (ft)<60.000	65	11.93%
60.000<=Max. Span Length (ft)<70.000	48	8.81%
70.000<=Max. Span Length (ft)<80.000	73	13.39%
80.000<=Max. Span Length (ft)<90.000	53	9.72%
90.000<=Max. Span Length (ft)<100.000	40	7.34%
100.000<=Max. Span Length (ft)<110.000	38	6.97%
110.000<=Max. Span Length (ft)<120.000	32	5.87%
120.000<=Max. Span Length (ft)<130.000	20	3.67%
130.000<=Max. Span Length (ft)<140.000	12	2.20%
140.000<=Max. Span Length (ft)<150.000	7	1.28%
150.000<=Max. Span Length (ft)<160.000	4	0.73%
160.000<=Max. Span Length (ft)<170.000	1	0.18%
170.000<=Max. Span Length (ft)<180.000	3	0.55%
180.000<=Max. Span Length (ft)<190.000	3	0.55%
190.000<=Max. Span Length (ft)<200.000	1	0.18%
200.000<=Max. Span Length (ft)<210.000	1	0.18%
210.000<=Max. Span Length (ft)<=220.000	1	0.18%
Total	545	100.00%

Appendix B – Michigan Virtis DB bridge demographics

Maximum Span Count

The following chart and graph represents the maximum span count for the structures in the Michigan sample database. Note that the vast majority of bridges are simple span structures.



Max. Number of Spans (NBI max_span_count)	Total	Percent %
Max. Number of Spans = 1	376	68.99%
Max. Number of Spans = 2	64	11.74%
Max. Number of Spans = 3	74	13.58%
Max. Number of Spans = 4	21	3.85%
Max. Number of Spans = 5	5	0.92%
Max. Number of Spans = 6	1	0.18%
Max. Number of Spans = 7	2	0.37%
Max. Number of Spans = 8	2	0.37%
Total	545	100.00%

Appendix B – Michigan Virtis DB bridge demographics

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Appendix C – Original BridgeOV documentation

Summary:

In summary, the program calculates the moments of simple span lengths of a user defined vehicle (input file) and compares that with predetermined moments of multiple classes.

The program is very simple and is written in the 'C' programming language. The software was rebuilt and run in Microsoft Developer Studio, 2008 with few problems. The source code provided to the researchers appears to be slightly different than the source code used to build the executable that accompanied the source code. This was evident because there are some output print statements that appear in the test case when run in the delivered EXE that don't appear in the researcher compiled version of the EXE for the same input. Additionally, the printed messages from the delivered EXE could not be located in the source code. Other than that, the results were identical. Below is a flowchart of the program (Figure C-113). The following pages provide a description of the program functions and output.

Appendix C – Original BridgeOV Documentation

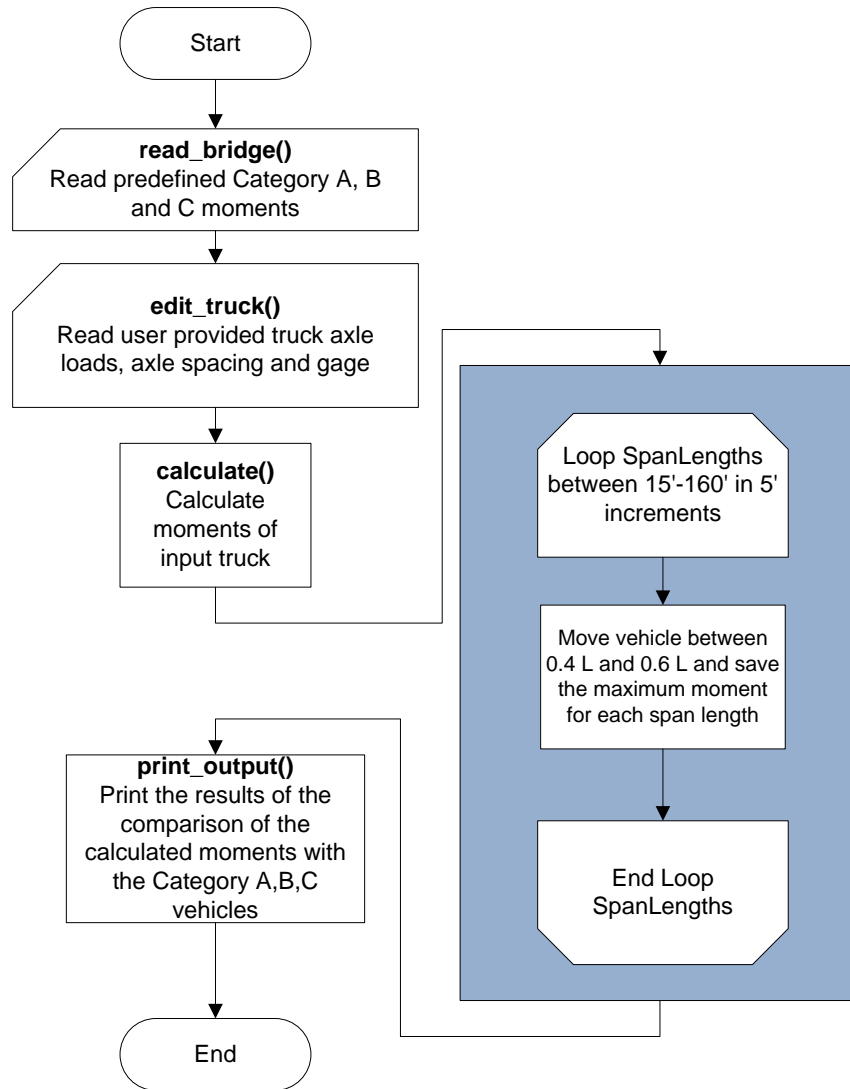


Figure C-113. BRIDGEOV.EXE flowchart

Appendix C – Original BridgeOV Documentation

Overview of Current Michigan overload program (BRIDGEOV.EXE)

- **banner(stdout,0)**
 - o Prints the disclaimer banner to the screen and waits for the user to hit return
- **read_bridge(struct bridge_t *bridge)** – Reads moments from a file for 3 truck classes for different span lengths and stores them in the passed structure 'bridge'. File is named 'CLSABC2U.TXT'. The format of the file is as follows:

```
# Any line beginning with a # sign is a comment line and will be ignored
# This information should not be modified in any way without approval
# It is important that the fields start in the proper columns.
# Anything other than the I, F, G, H, and B columns will be ignored.
#0000000011111111112222222222333333333344444444445
#23456789012345678901234567890123456789012345678901234567890
#AAAA III FFFFFFFF GGGGGGGG HHHHHHHH BBBBBBBB
#MOM CLASS      A          B          C          2U77
#
SPAN= 010      195.0      195.0      195.0      92.9
SPAN= 011      215.4      214.5      214.5      102.2
SPAN= 012      234.8      234.0      234.0      111.5
.
SPAN= 199     11912.7     10160.5     7989.6     7691.6
SPAN= 200     11986.2     10223.2     8038.9     7732.9
```

The 'SPAN= 010' is the span length. The A,B, and C columns are used, but the 2U77 (i.e. B), while it is read, it does not appear to be used for anything. The values in the A, B and C columns are echoed in the output (in increments of 5' lengths) are compared against the calculated simple span live load moment

- **edit_truck(truck_t *truck)** – this function reads in the truck axle load, axle spacing, and gage from an input file. Once read in, the program permits modifying of the truck data that is read in. The function also permits entering a truck manually. The vehicle gage factors the axle load by the following formula
 - o **AxleLoad = InputAxleLoad * ((InputGage + 8.0)/16.0)**

Therefore if the InputGage = 8.0, then the AxleLoad = InputAxleLoad

- **calculate(struct truck_t *truck, struct results_t *results)** – using simple span influence lines, this function calculates truck moments for the input vehicle.
 - o Impact is applied to the vehicle and is calculated as

$$I = \text{Min}(1 + (50 / (125 + L)) , 1.3)$$

With:

L = span length

Appendix C – Original BridgeOV Documentation

- Calculates and saves maximum moments for the truck for simple spans (from 15' to 160' in increments of 5') and ultimately compares them with the Class A, B, and C moments read in from the file 'CLSABC2U.TXT'.
 - Only looks at influence points from 0.4L location to the 0.6L location of the simple span.
- **print_output(FILE *output ...)** – prints the output results to stdout (for screen printing) and/or to a file. (Output example shown below)

Maximum allowable moments for
simple span bridges between 15-160 feet.

Simple span (ft)	Truck Moment (kip [ft])	Class A (kip [ft])	Class B (kip [ft])	Class C (kip [ft])	
15	243.8	329.5	292.5	292.5	
20	364.0	473.6	410.0	390.0	
25	520.0	634.0	537.3	487.5	NO
30	677.0	808.3	690.4	597.0	NO
35	835.4	1022.7	861.3	726.0	NO
40	995.3	1245.2	1035.9	867.1	NO
45	1150.2	1468.4	1232.0	1019.6	NO
50	1301.8	1723.0	1428.8	1187.6	NO
55	1451.9	1991.5	1647.2	1377.7	NO
60	1601.0	2257.8	1881.8	1578.7	NO
65	1749.0	2522.2	2119.9	1778.5	
70	1895.7	2803.7	2356.5	1977.0	
.	
150	4141.1	8265.1	7049.3	5679.1	
155	4276.8	8642.0	7370.7	5912.8	
160	4412.1	9017.6	7691.2	6145.7	

From table
CLSABC2U.TXT

Truck moments for the vehicle input by the user. Maximum moments are determined by simple span influence lines. Influence lines are loaded from 0.4L to 0.6L

For unknown span lengths, brov8 can drive over the class of bridge listed below:

Class A	Class B	Class C
YES	YES	NO

For Bridge Class refer to MDOT map and table titled "Table of Bridges with Restricted Load Limits" and MDOT table "Overloads Permissible on Bridges."

Appendix D – Permit Vehicle Review

Appendix D – Permit Vehicle Review

The following table provides all 31 permit vehicles originally considered, with several similar vehicles removed to reduce the list to 25. The removed vehicles are shown with a strikethrough and are not represented in the subsequent plots.

Table D-25. List of permit vehicles reviewed

Name	PermitID	Number Axles	Gross Weight	Total Length	Axle Spacings	Axle Loads
MIPermit0001	111000582302	5	136.65	25.42	7.666667,5.583333,6.583333,5.583333	27.9,27.9,26.95,26.95,26.95
MIPermit0002	111000157102	5	143.50	23.83	7.91667,5.25,5.333, 5.333	28.7,28.7,28.7,28.7,28.7
MIPermit0003	111000222302	6	145.44	44.42	12.16667,4.25,20,4,4	20.36,28.82,28.82,22.48,22.48,22.48
MIPermit0004	111000273402	6	150.22	29.92	4.5,4.5,11.91667,4.5,4.5	19.12,19.37,11.17,34.34,34.04,32.18
MIPermit0005	111000564202	6	152.00	63.17	12.33333,4.166667,37.66667,4.5,4.5	12,28,28,28,28,28
MIPermit0006	111000391002	7	161.50	53.33	10.5,4.5,4.5,25,4.5,4.333333	16,24,24,24,24.5,24.5,24.5
MIPermit0007	111000361802	6	162.00	58.50	12,4.5,33,4.5,4.5	18,30,30,28,28,28
MIPermit0008	111000036002	6	172.20	34.75	5.583333,10.5,5.416667,7.833333,5.416667	28.7,28.7,28.7,28.7,28.7,28.7
MIPermit0009	111000172302	9	184.40	99.00	18.16667,4.5,14.16667,4.5,34.5,4.5,14.16667,4.5	14,21,21,21,21,22.2,22.2,21,21
MIPermit0010	111000427300	12	194.00	108.50	16,4.5,4.5,15,4.5,30,4.5,4.5,4.5,16,4.5	12,14,14,14,20,20,15,15,15,15,20,20
MIPermit0011	111000180502	7	198.70	64.50	11,4,36,4.5,4.5,4.5	18.7,27.7,27.7,31.7,31.7,30.6,30.6
MIPermit0012	111000028002	7	200.90	37.92	6.083333,9,5.416667,5.416667,6.583333,5.416667	28.7,28.7,28.7,28.7,28.7,28.7,28.7

Appendix D – Permit Vehicle Review

Name	PermitID	Number Axles	Gross Weight	Total Length	Axle Spacings	Axle Loads
MIPermit0013	111000469500	8	207.95	70.33	12.33333,4.833333,5.166667,36,4,4,4	8.141,7.449,31.668,32.013,32.108,32.319, 32.154,32.1
MIPermit0014	111000318802	8	208.00	69.00	11,4.5,4.5,36,4.333333,4.333333,4.333333	19,28,30.5,30.5,25,25,25,25
MIPermit0015	111000264000	13	224.00	122.33	14.41667,4.583333,4.583333,15.33333,5,5,39.3333,5,5,14.08333,5,5	14,18,18,18,18,18,18,17,17,17,17,17,17
MIPermit0016	111000122002	9	234.60	72.33	11.16667,4,4.333333,33.83333,4.5,4.5,5,5	18,25,30.8,30.8,28,28,25,25,24
MIPermit0017	111000256902	9	244.00	83.00	17.5,4.5,4.5,36.5,5,5,5,5	14,30,30,30,28,28,28,28, 28
MIPermit0018	111001079000	18	411.2	150.58	14.75,4.5,4.5,9.416667,4.5,4.5,9.416667,4.5,4.5,48.66667,4.5,9.416667,4.5,4.5,9.416667,4.5,4.5	11.7,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5,23.5
MIPermit0019	111000650702	10	270	79.66	11.83333,4.666667,7.25,4.166667,4.166667,35.08333,4.166667,4.166667,4.166667	18,28,28,28,28,28,28,28,28,28,28
MIPermit0020	111000552802	10	252	79.66	11.83333,4.666667,7.25,4.166667,4.166667,35.08333,4.166667,4.166667,4.166667	18,26,26,26,26,26,26,26,26,26,26
MIPermit0021	111002067902	10	246.5	79.5	12.16667,4.166667,7,4.166667,34,4.5,4.5,4.5,4.5	14,27.5,27.5,27.5,27.5,24.5,24.5,24.5,24.5,24.5
MIPermit0022	111000896302	10	246.3	93.41	12,4.5,13.58333,4.5,31.83333,4.5,4.5,13.5,4.5	18,23.65,23.65,28,28,25,25,25,25,25
MIPermit0023	111001324800	9	289.2	89.83	12,4.5,12,4.5,43.33333,4.333333,4.833333,4.333333	16,27.3,27.3,49.7,49.7,29.8,29.8,9.8,29.8,29.8
MIPermit0024	111001883502	9	217.6	72	11.16667,4,4,33.83333,4.5,4.5,5,5	18,24,30.8,30.8,24,24,22,22,22
MIPermit0025	111001738902	8	193.88	71.417	15.16667,4.166667,4.416667,35.41667,4.083333,4.083333,4.083333	14,25.697,25.697,25.697,25.697,25.697,25.697,25.697,25.698
MIPermit0026	111001281802	8	191	71.917	11.75,4,4.25,4.25,39,4.333333,4.333333	16,16,24,27,27,27,27,27

Appendix D – Permit Vehicle Review

Name	PermitID	Number Axles	Gross Weight	Total Length	Axle Spacings	Axle Loads
MIPermit0027	111000751002	8	185.2	62.167	12,4.333333,4.333333,29,4.166667,4.166667,4.166667	18,19,26.7,26.7,23.7,23.7,23.7,23.7
MIPermit0028	111001353402	7	187.6	65	14,4.5,34,4.166667,4.166667,4.166667	14,30.8,30.8,28,28,28,28
MIPermit0029	111001780902	7	172.8	60.833	12.16667,4.166667,32,4.166667,4.166667,4.166667	14,30.8,30.8,24.3,24.3,24.3,24.3
MIPermit0030	111000692602	4	112.04	17	5,7,5	29.7,29.48,26.58,26.28
MIPermit0031	111001491702	3	61.2	19.833	15.5,4.333333	20,20.6,20.6

Note: Vehicles with strikethrough are not shown in the graphs.

Appendix D – Permit Vehicle Review

The following table provides a cross reference of the vehicle grouping and the subsequent figures.

Table D-26. Permit Table groupings for plotting

Vehicle name	Permit ID	# Axles	Weight	Length	Figure
MIP-0031	111001491702	3	61.2	19.8	Figure D-115
MIP-0030	111000692602	4	112.0	17.0	
MIP-0002	111000157102	5	143.5	23.8	
MIP-0008	111000036002	6	172.2	34.8	Figure D-116
MIP-0007	111000361802	6	162.0	58.5	
MIP-0004	111000273402	6	150.2	29.9	
MIP-0003	111000222302	6	145.4	44.4	
MIP-0012	111000028002	7	200.9	37.9	Figure D-117
MIP-0011	111000180502	7	198.7	64.5	
MIP-0029	111001780902	7	172.8	60.8	
MIP-0006	111000391002	7	161.5	53.3	
MIP-0013	111000469500	8	208.0	70.3	Figure D-118
MIP-0025	111001738902	8	193.9	71.4	
MIP-0026	111001281802	8	191.0	71.9	
MIP-0027	111000751002	8	185.2	62.2	
MIP-0023	111001324800	9	289.2	89.8	Figure D-119
MIP-0017	111000256902	9	244.0	83.0	
MIP-0016	111000122002	9	234.6	72.3	
MIP-0009	111000172302	9	184.4	99.0	
MIP-0019	111000650702	10	270.0	79.7	Figure D-120
MIP-0021	111002067902	10	246.5	79.5	
MIP-0022	111000896302	10	246.3	93.4	
MIP-0010	111000427300	12	194.0	108.5	Figure D-121
MIP-0015	111000264000	13	224.0	122.3	
MIP-0018	111001079000	18	411.2	150.6	

Appendix D – Permit Vehicle Review

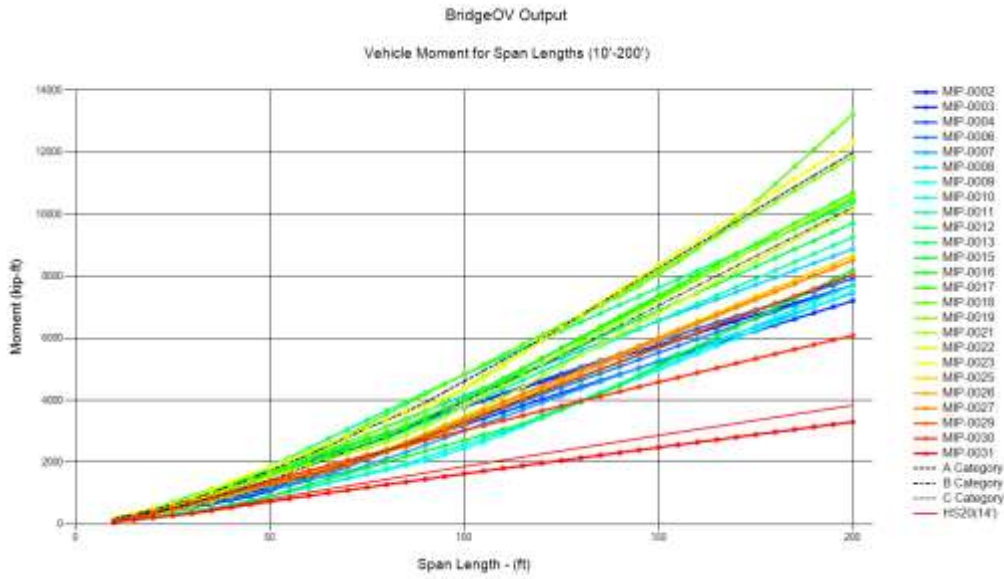


Figure D-114. All Michigan permit vehicles (from permit list provided from MDOT)

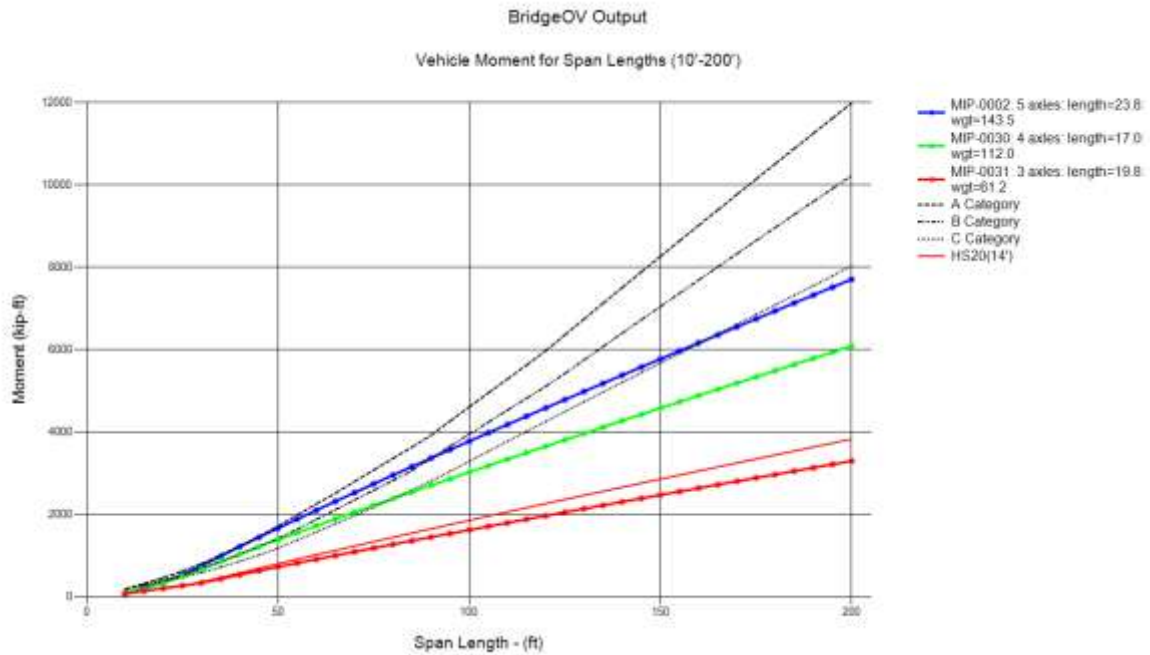


Figure D-115. Vehicles MIP-0002, 0030, 0031 (3, 4, and 5 axles) moment

Appendix D – Permit Vehicle Review

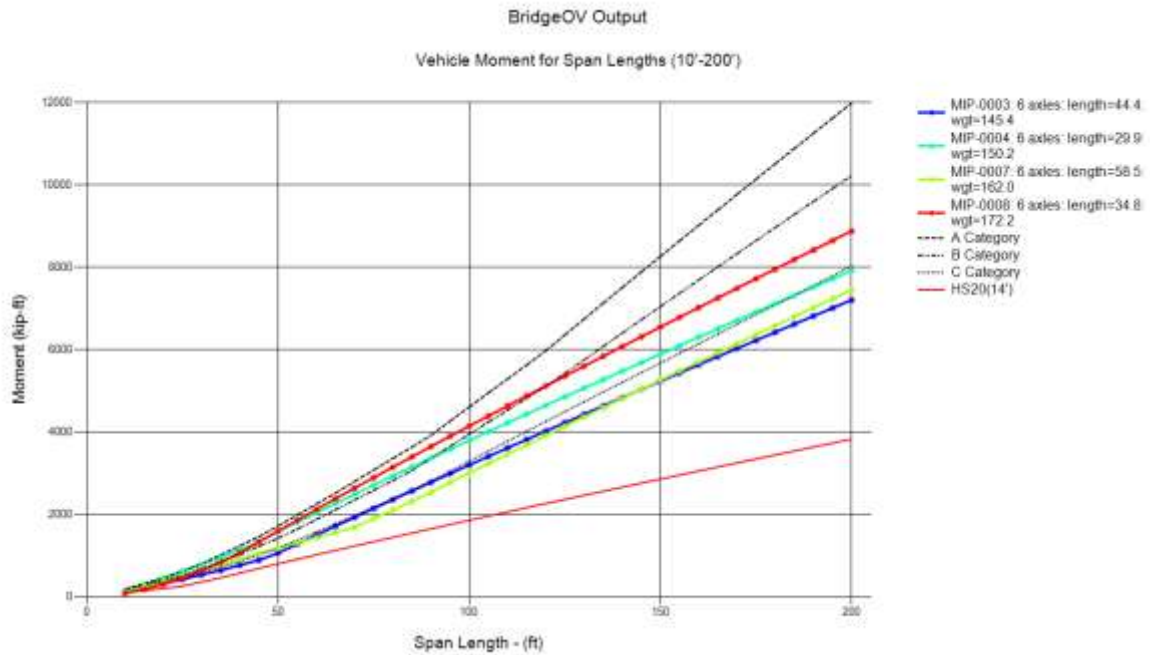


Figure D-116. Vehicles MIP-0003, 0004, 0007,0008 (6 axes) moment

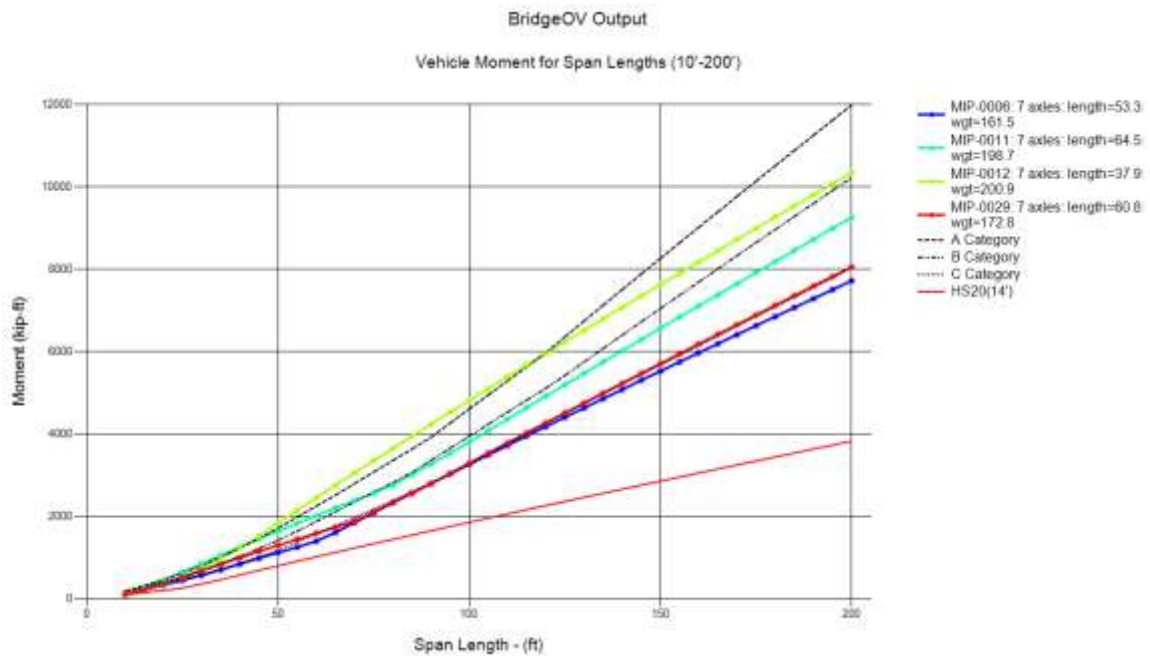


Figure D-117. Vehicles MIP-0006, 0011, 0012, 0029 (7 axes) moment

Appendix D – Permit Vehicle Review

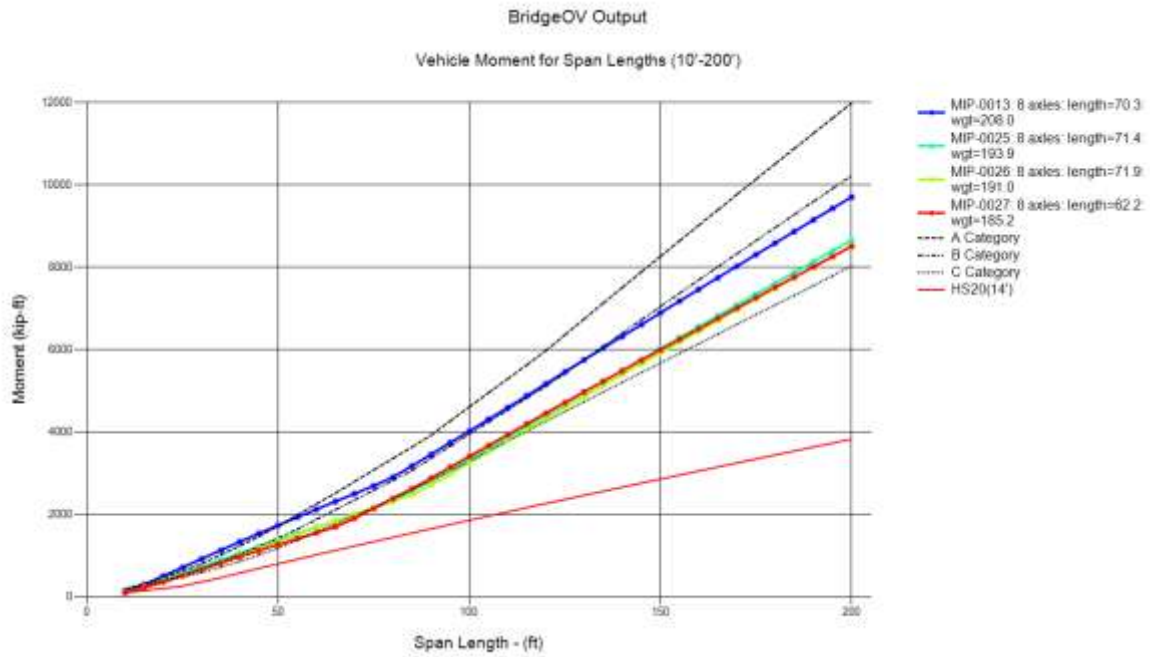


Figure D-118. Vehicles MIP-0013, 0025, 0026, 0027 (8 axles) moment

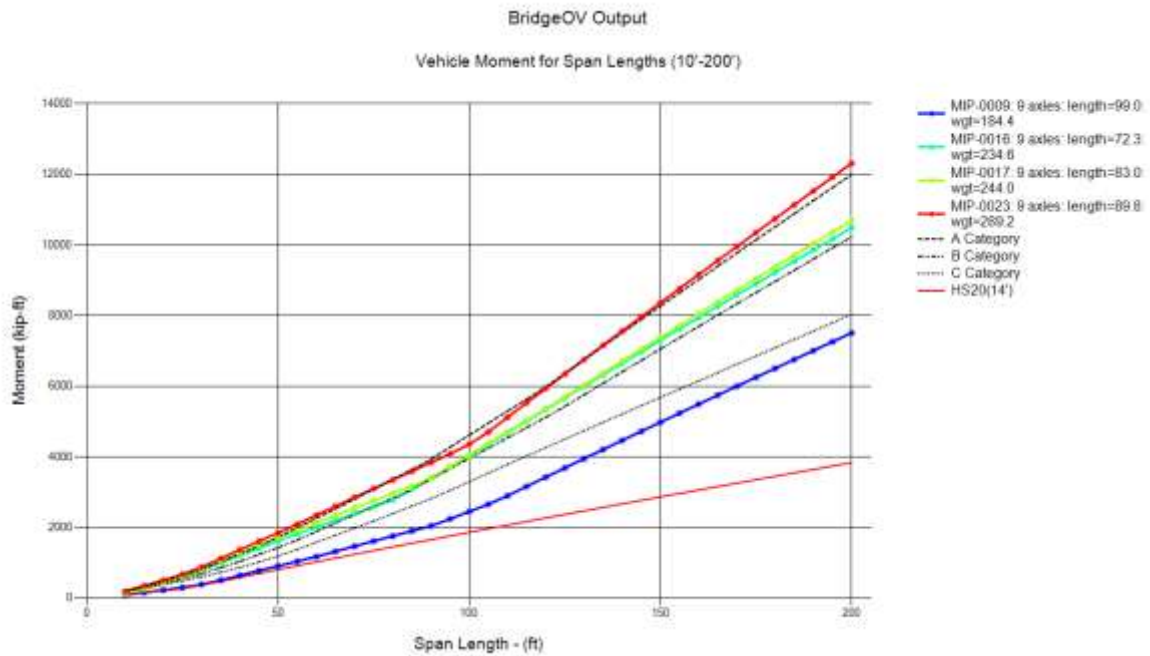


Figure D-119. Vehicles MIP-0009, 0016, 0017, 0023 (9 axles) moment

Appendix D – Permit Vehicle Review

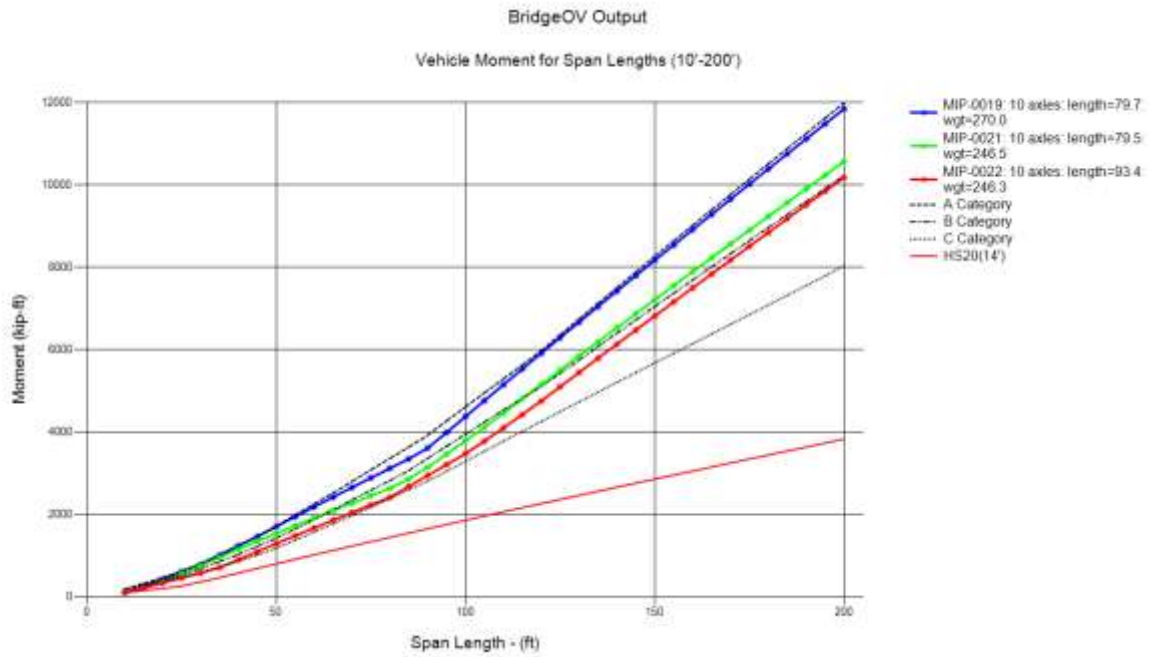


Figure D-120. Vehicles MIP-0019, 0021, 0022 (10 axles) moment

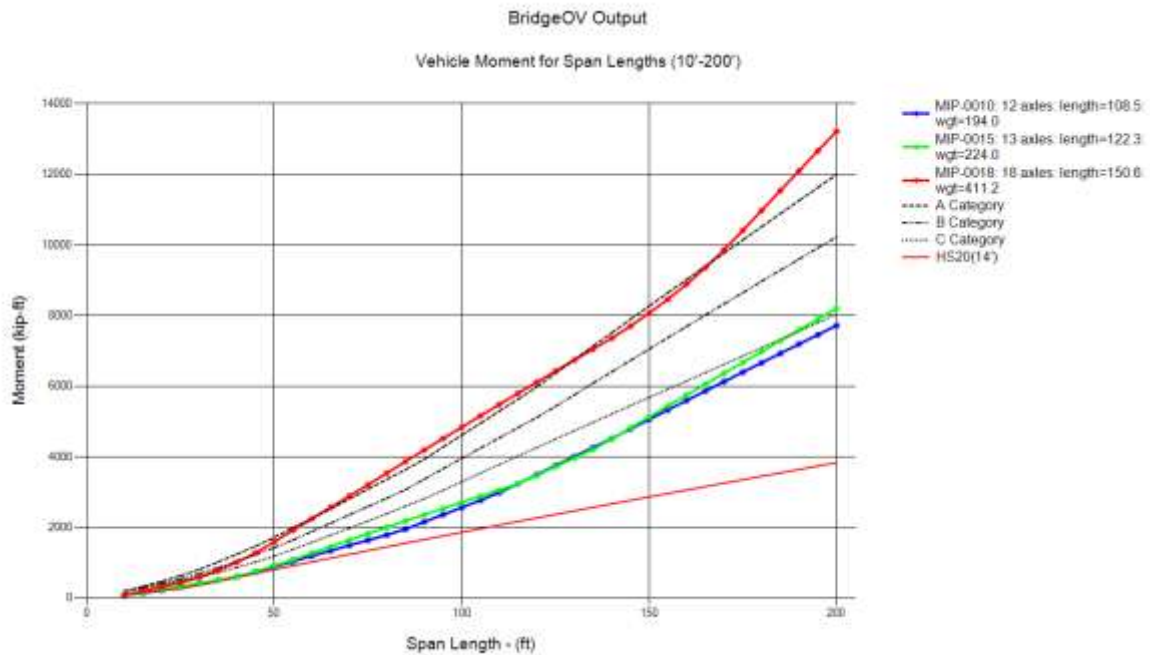


Figure D-121. Vehicles MIP-0010, 0015, 0018 (12, 13 and 18 axles) moment

Appendix E – Permit Vehicles - Virtis Ratings

This appendix provides a review of 17 permit vehicles selected from a list provided by MDOT. Comparisons to Virtis ratings and MDOT BridgeOV ratings are made.

Table E-27. Summary of results – comparing Virtis/BridgeOV – 225 bridges – 17 permit vehicles

Name	PermitID	Number Axles	Gross Weight	Total Length	Oper Ratings >= 1.0	Oper Ratings < 1.0	Total	% passed	Passed Bridge OV?			Span Lengths Not Passed (ft) 5ft increments		
									A	B	C	A	B	C
MIPermit0001	111000582302	5	137	25	156	69	225	69.3%	YES	NO	NO	-	35-70	30-125
MIPermit0002	111000157102	5	144	24	127	98	225	56.4%	YES	NO	NO	-	25-90	25-160
MIPermit0003	111000222302	6	145	44	204	21	225	90.7%	YES	YES	YES	-	-	-
MIPermit0004	111000273402	6	150	30	123	102	225	54.7%	YES	NO	NO	-	15-90	15-160
MIPermit0005	111000564202	6	152	63	194	31	225	86.2%	YES	YES	NO	-	-	25-50
MIPermit0006	111000391002	7	162	53	197	28	225	87.6%	YES	YES	YES	-	-	-
MIPermit0007	111000361802	6	162	59	186	39	225	82.7%	YES	YES	NO	-	-	25-50
MIPermit0008	111000036002	6	172	35	129	96	225	57.3%	YES	NO	NO	-	40-120	30-160
MIPermit0009	111000172302	9	184	99	218	7	225	96.9%	YES	YES	YES	-	-	-
MIPermit0010	111000427300	12	194	109	218	7	225	96.9%	YES	YES	YES	-	-	-
MIPermit0011	111000180502	7	199	65	117	108	225	52.0%	NO	NO	NO	25-40	20-70	20-160
MIPermit0012	111000028002	7	201	38	85	140	225	37.8%	NO	NO	NO	45-115	30-160	25-160
MIPermit0013	111000469500	8	208	70	93	132	225	41.3%	NO	NO	NO	20-50	15-125	15-160
MIPermit0014	111000318802	8	208	69	158	67	225	70.2%	YES	NO	NO	-	25-40	90-160
MIPermit0015	111000264000	13	224	122	218	7	225	96.9%	YES	YES	YES	-	-	-
MIPermit0016	111000122002	9	235	72	122	103	225	54.2%	YES	NO	NO	-	20-70, 85-160	20-160
MIPermit0017	111000256902	9	244	83	102	123	225	45.3%	NO	NO	NO	30-45	25-160	20-160
HS-20-44	na	3	72	28-44	219	6	225	97.3%	YES	YES	YES	-	-	-

Table E-27 shows a breakdown of the 225 bridges run with the 17 permit vehicles using BRASS/Virtis LFR in version 6.3 of Virtis. The Number of bridges passed for each vehicle is represented in column 6, the percentage passed is column 9 (see also Figure E-122).

Columns 10-12 represent the BridgeOV results (whether or not they passed Classes A, B, and C) while columns 13-16 represent the span lengths (from 15'-160' in increments of 5') that the vehicle did not pass.

Virtis rating value plots for HS20 and the first 3 permit vehicles are provided in Figure E-123 through Figure E-126.

A sample BridgeOV file for vehicle MIPer0001 is provided at the end of this appendix

APPENDIX E – Permit Vehicles – Virtis Ratings

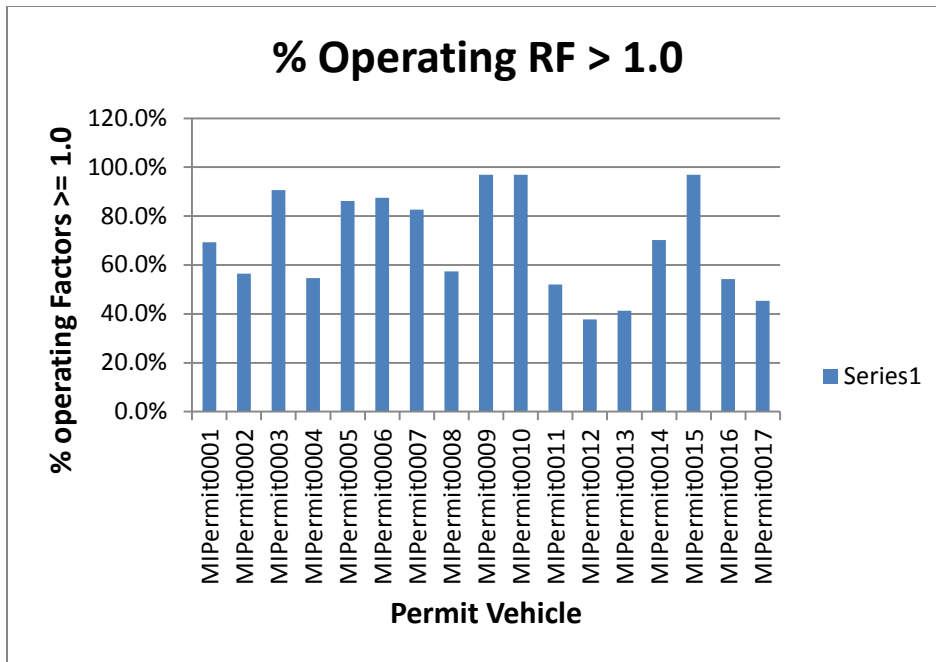


Figure E-122. Operating rating factors > 1.0 for the 17 vehicles listed in Table E-27

HS-20 Rating Plot

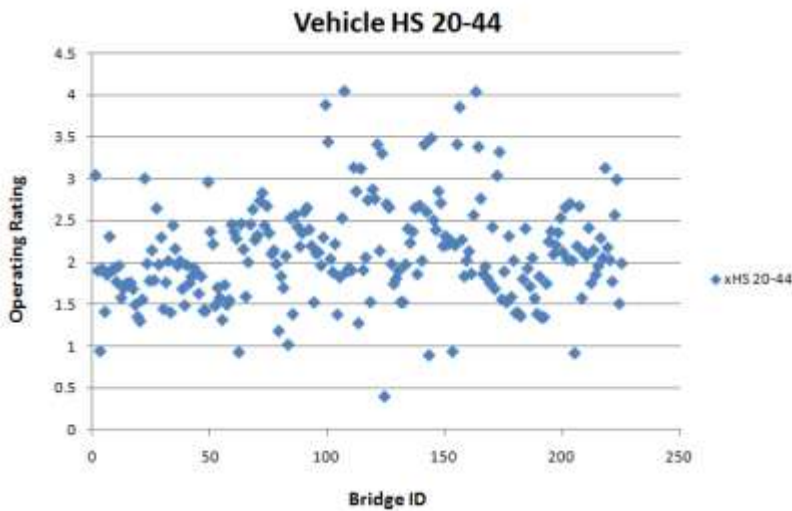


Figure E-123. Operating rating factors vs. Virtis BridgeID for HS 20-44

APPENDIX E – Permit Vehicles – Virtis Ratings

Operating Rating Plots

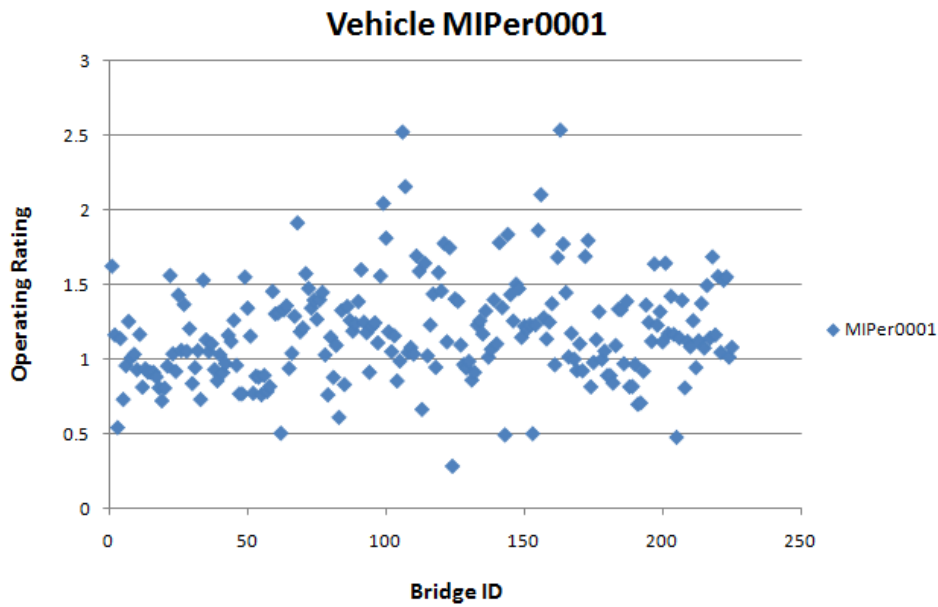


Figure E-124. Operating rating factors vs. Virtis Bridge ID for permit vehicle MIPer0001 (see Table E-27)

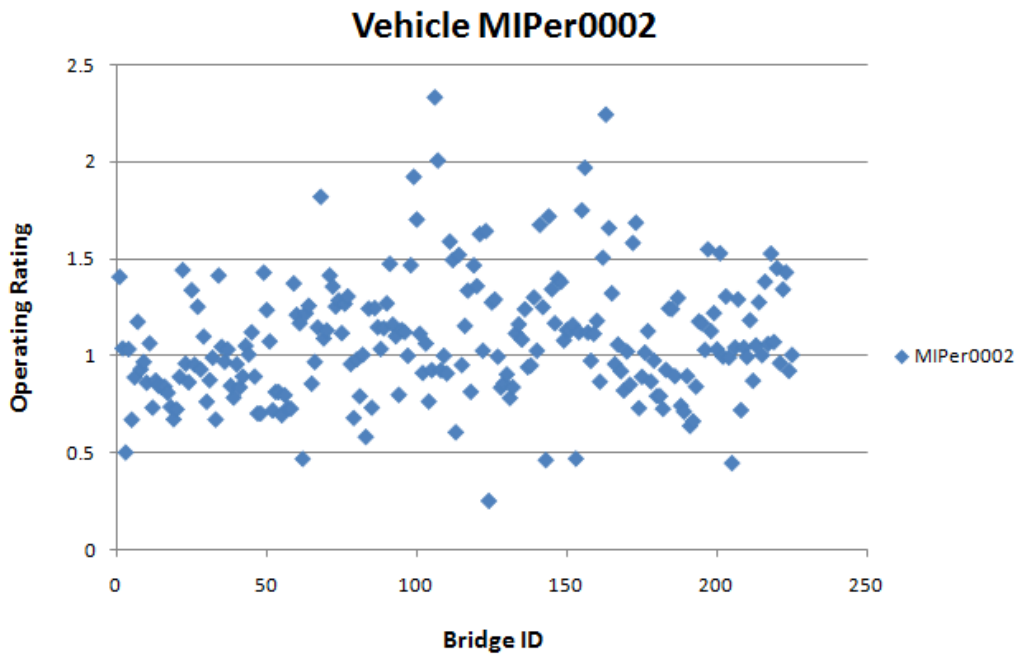


Figure E-125. Operating rating factors vs. Virtis Bridge ID for permit vehicle MIPer0002 (see Table E-27)

APPENDIX E – Permit Vehicles – Virtis Ratings

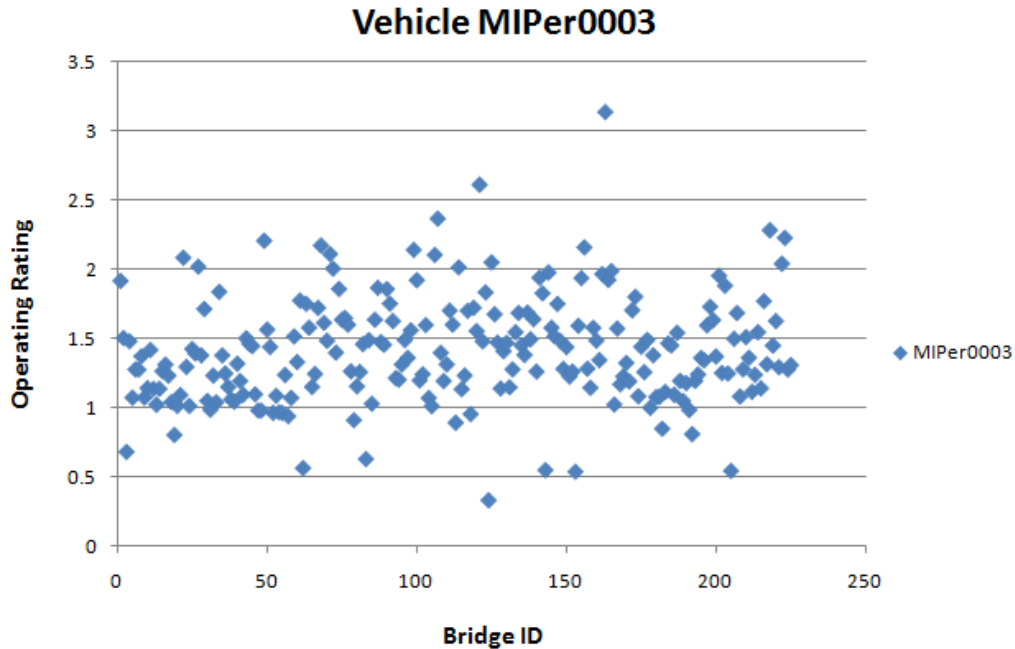


Figure E-126. Operating rating factors vs. Virtis Bridge ID for permit vehicle MIPer0003 (see Table E-27)

Sample BridgeOV output

Bridge overload (Bridgeov) Version 1.0
Copyright (c) 1991 - Freeware program.

This program is of public domain and may be freely distributed and used.
Any commercial redistribution of this program or part of it is
however prohibited.

This program was jointly developed by the Transportation Technology
Transfer Center located at the Michigan Technological University and
the Michigan Department of Transportation.
Original program written by: David D. Abbott, P.E.
Conversions and Updates by: David Paxson and Markus Varsta.

This program will calculate truck moments to determine whether the
given truck should be allowed over bridges of various spans and classes.

Pathname: MIPermit0001.TXT

Run Date: Thu Jun 30 15:59:12 2011

Run name: MIPer0001

Axle #	Gage (feet)	Load (kips)	Aj-Ld (kips)	Dist (feet)	To-Dis (feet)	To-Load (kips)	To-Aj Load (kips)
1	8.00	27.90	27.90	0.00	0.00	27.9	27.9
2	8.00	27.90	27.90	7.67	7.67	55.8	55.8
3	8.00	26.95	26.95	5.58	13.25	82.8	82.8
4	8.00	26.95	26.95	6.58	19.83	109.7	109.7
5	8.00	26.95	26.95	5.58	25.42	136.7	136.7

Maximum allowable moments for

APPENDIX E – Permit Vehicles – Virtis Ratings

simple span bridges between 15-160 feet.

Simple span (ft)	Truck Moment (kip [ft])	Class A (kip [ft])	Class B (kip [ft])	Class C (kip [ft])
15	182.3	329.5	292.5	292.5
20	315.2	473.6	410.0	390.0
25	468.4	634.0	537.3	487.5
30	662.3	808.3	690.4	597.0 NO
35	884.4	1022.7	861.3 NO	726.0 NO
40	1106.5	1245.2	1035.9 NO	867.1 NO
45	1322.5	1468.4	1232.0 NO	1019.6 NO
50	1533.5	1723.0	1428.8 NO	1187.6 NO
55	1742.3	1991.5	1647.2 NO	1377.7 NO
60	1949.1	2257.8	1881.8 NO	1578.7 NO
65	2153.9	2522.2	2119.9 NO	1778.5 NO
70	2357.0	2803.7	2356.5 NO	1977.0 NO
75	2558.5	3083.5	2591.7	2181.4 NO
80	2758.5	3361.5	2825.4	2388.0 NO
85	2957.1	3638.0	3069.6	2601.4 NO
90	3154.4	3926.8	3365.8	2813.8 NO
95	3350.5	4270.5	3660.4	3050.4 NO
100	3545.5	4612.4	3953.5	3294.6 NO
105	3739.4	4952.6	4245.1	3537.6 NO
110	3932.4	5291.3	4535.4	3779.5 NO
115	4124.4	5629.1	4824.3	4020.3 NO
120	4315.6	5975.3	5112.0	4260.0 NO
125	4505.9	6360.7	5424.9	4498.7 NO
130	4695.5	6744.5	5752.2	4736.5
135	4884.4	7126.7	6078.3	4973.4
140	5072.5	7507.5	6403.1	5209.4
145	5260.1	7887.0	6726.8	5444.6
150	5447.0	8265.1	7049.3	5679.1
155	5633.3	8642.0	7370.7	5912.8
160	5819.2	9017.6	7691.2	6145.7

For unknown span lengths, MIPer0001 can drive over the class of bridge listed below:

Class A	Class B	Class C
YES	NO	NO

For Bridge Class refer to MDOT map and table titled "Table of Bridges with Restricted Load Limits" and MDOT table "Overloads Permissible on Bridges."

APPENDIX E – Permit Vehicles – Virtis Ratings

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Appendix F – Revised CLSABC2U.txt File

The following is the revised file used by BridgeOV and stores the predefined moment and shear envelopes for the 20 Class A,B, and C vehicles. A similar file with LRFR moments based on varying load factors is also provided with the program as CLSABC2U_LRFR.txt.

New File 'CLSABC2U.TXT'

```
# Any line beginning with a # sign is a comment line and will be ignored
# This information should not be modified in any way without approval
# It is important that the fields start in the proper columns.
# Anything other than the I, F, G, H, and B columns will be ignored.
#00000000111111111111222222222233333333334444444444
#23456789012345678901234567890123456789012345678901234567890
#AAAA III FFFFFFFF GGGGGGGG HHHHHHHH BBBB BBBB
#MOM CLASS      A      B      C      2U77      HS20 (14 ft)  A      B      C      Shear 2 equal spans
#                A      B      C                A      B      C                A      B      C
#
SPAN= 010  195.1  191.9  185.4  92.9  104.0  93.7  81.2  74.2  99.3  86.1  75.1
SPAN= 011  215.5  211.0  203.9  102.2  114.4  95.8  83.1  74.2  101.4  87.9  76.6
SPAN= 012  243.8  230.2  222.4  111.5  124.8  97.6  84.6  74.2  103.0  89.3  77.9
SPAN= 013  272.3  249.4  240.9  120.8  135.2  99.1  85.9  74.9  105.0  91.0  79.4
SPAN= 014  300.8  268.6  259.5  130.1  145.6  100.5  87.0  75.9  106.6  92.4  80.6
SPAN= 015  329.6  287.7  278.0  139.4  156.0  101.8  88.0  76.7  107.9  93.5  81.5
SPAN= 016  358.4  310.6  296.5  160.6  166.4  103.8  88.8  77.5  109.3  94.4  82.3
SPAN= 017  387.2  335.6  315.0  181.7  176.8  105.6  91.6  79.0  111.7  96.8  82.9
SPAN= 018  416.1  360.6  333.6  202.8  187.2  108.4  94.0  80.3  114.9  99.6  84.3
SPAN= 019  445.0  385.7  352.1  223.9  197.6  110.9  96.2  81.9  117.7  102.0  86.7
SPAN= 020  474.0  410.8  370.6  245.1  208.0  113.2  98.1  83.8  120.2  104.2  88.8
SPAN= 021  504.2  435.9  389.1  269.9  218.4  115.2  99.9  85.5  122.4  106.1  90.8
SPAN= 022  536.4  461.0  407.7  295.8  228.8  117.1  101.5  87.1  124.4  107.8  92.5
SPAN= 023  568.5  486.1  426.2  325.3  239.2  119.1  103.0  88.7  126.2  109.4  94.0
SPAN= 024  601.0  511.3  445.8  354.9  249.6  121.6  104.3  90.3  128.7  110.8  95.8
SPAN= 025  634.3  537.3  467.9  384.5  266.2  123.9  105.6  91.8  131.3  112.1  97.5
SPAN= 026  667.7  566.5  493.7  414.1  286.2  126.0  106.7  93.2  133.7  113.9  99.0
SPAN= 027  701.0  597.5  519.4  443.6  306.2  128.0  107.8  94.5  135.9  116.2  100.8
SPAN= 028  735.3  628.5  545.2  476.6  326.1  129.8  108.7  95.7  137.9  118.1  102.5
SPAN= 029  771.6  659.5  571.0  510.2  346.1  131.6  109.7  97.2  139.7  119.8  104.0
SPAN= 030  808.0  690.6  596.8  543.9  366.1  133.2  110.5  98.9  141.4  121.3  105.3
SPAN= 031  846.4  721.8  622.6  577.7  386.0  134.7  111.3  100.5  143.0  122.7  106.5
SPAN= 032  889.5  756.7  648.4  611.4  406.0  136.1  112.4  102.0  144.4  123.9  108.0
SPAN= 033  933.9  791.6  674.1  645.1  426.0  137.4  113.5  103.4  145.8  124.9  109.6
SPAN= 034  978.3  826.4  699.9  678.9  446.4  138.6  114.9  104.7  147.1  125.9  111.0
SPAN= 035  1022.7  861.3  725.7  712.6  469.4  139.8  116.4  106.0  148.9  126.7  112.4
SPAN= 036  1067.1  899.1  751.5  746.4  492.5  140.9  117.8  107.1  151.0  127.5  113.7
SPAN= 037  1111.6  941.6  777.3  780.1  515.5  142.3  119.7  108.2  153.7  129.3  115.0
SPAN= 038  1156.2  984.1  805.8  813.9  538.6  145.1  122.0  109.3  156.3  131.4  116.1
SPAN= 039  1203.8  1026.6  836.4  847.6  561.7  147.7  124.2  110.3  158.9  133.6  117.2
SPAN= 040  1253.8  1069.1  867.2  881.4  584.7  150.3  126.3  111.3  161.8  136.0  118.2
SPAN= 041  1303.8  1111.8  898.0  915.1  607.8  152.6  128.3  112.2  164.5  138.3  119.2
SPAN= 042  1353.2  1153.9  928.6  952.3  630.6  154.8  130.2  113.0  167.0  140.4  120.0
SPAN= 043  1401.2  1194.8  958.3  989.9  652.8  156.8  131.8  113.6  169.2  142.2  120.7
SPAN= 044  1449.1  1235.7  987.9  1027.4  675.0  158.6  133.4  114.3  171.3  144.0  121.3
SPAN= 045  1496.9  1276.5  1019.6  1064.7  697.1  160.4  134.8  114.8  173.2  145.6  122.1
SPAN= 046  1544.6  1317.2  1052.3  1102.0  719.2  162.0  136.2  115.4  175.0  147.2  123.4
SPAN= 047  1592.2  1357.7  1084.9  1142.6  741.3  163.6  137.6  116.3  176.8  148.6  124.6
SPAN= 048  1639.7  1398.2  1117.5  1184.7  763.3  165.1  138.8  117.5  178.4  150.0  125.8
SPAN= 049  1687.1  1438.6  1151.1  1226.7  785.3  166.6  140.0  118.5  180.0  151.3  126.9
SPAN= 050  1734.4  1479.0  1188.3  1268.5  807.2  167.9  141.2  119.6  181.5  152.5  127.9
SPAN= 051  1783.0  1520.4  1225.4  1310.4  829.0  169.2  142.3  120.6  182.8  153.7  129.1
SPAN= 052  1835.1  1564.8  1262.4  1352.4  850.9  170.5  143.3  121.5  184.2  154.8  130.4
SPAN= 053  1887.1  1609.2  1299.5  1394.3  872.7  171.7  144.3  122.4  185.4  155.9  131.7
SPAN= 054  1939.0  1653.4  1336.7  1436.0  894.5  172.8  145.3  123.3  186.6  156.9  132.9
SPAN= 055  1991.5  1697.5  1376.9  1477.8  916.3  173.9  146.2  124.4  187.7  157.8  134.1
SPAN= 056  2045.0  1741.6  1417.0  1519.4  938.0  174.9  147.0  125.4  188.8  158.7  135.2
SPAN= 057  2098.4  1785.6  1457.1  1560.9  959.7  175.9  147.9  126.3  189.8  159.5  136.2
SPAN= 058  2151.7  1829.5  1497.0  1602.4  981.3  176.9  148.7  127.2  190.8  160.4  137.2
SPAN= 059  2204.8  1873.3  1537.0  1643.7  1002.9  177.8  149.4  128.1  191.7  161.1  138.1
SPAN= 060  2257.9  1917.0  1577.3  1676.1  1024.5  178.6  150.2  128.9  192.5  161.9  139.1
SPAN= 061  2310.9  1960.6  1617.6  1722.8  1046.0  179.5  150.9  129.8  193.4  162.5  139.9
SPAN= 062  2363.7  2004.2  1657.7  1769.5  1067.5  180.3  151.6  130.5  194.2  163.2  140.7
SPAN= 063  2416.5  2047.7  1697.8  1816.0  1089.0  181.1  152.2  131.3  194.9  163.8  141.5
SPAN= 064  2469.2  2091.1  1737.7  1862.5  1110.4  181.8  152.8  132.0  195.6  164.4  142.3
```

APPENDIX F – CLSABC2U.TXT file used by BridgeOV

SPAN= 065	2522.1	2134.4	1777.7	1908.8	1131.7	182.5	153.4	132.7	196.3	165.8	143.0
SPAN= 066	2578.6	2177.6	1817.5	1955.1	1153.1	183.2	154.0	133.4	197.0	167.4	143.7
SPAN= 067	2635.0	2220.8	1857.3	2001.4	1174.4	183.9	155.0	134.0	197.6	168.9	144.4
SPAN= 068	2691.3	2263.9	1897.0	2047.5	1195.7	184.5	156.3	134.6	198.8	170.4	145.0
SPAN= 069	2747.6	2308.8	1936.6	2093.6	1217.0	185.1	157.6	135.2	200.5	171.9	145.6
SPAN= 070	2803.7	2356.0	1976.7	2139.6	1238.2	185.7	158.8	135.8	202.1	173.3	146.2
SPAN= 071	2859.8	2403.1	2017.8	2185.5	1259.5	186.7	160.0	136.3	203.7	174.6	146.7
SPAN= 072	2915.7	2450.1	2058.8	2231.4	1280.7	188.1	161.2	136.9	205.2	175.9	147.3
SPAN= 073	2971.6	2497.1	2099.8	2277.2	1301.8	189.4	162.3	137.4	206.6	177.1	147.8
SPAN= 074	3027.4	2543.9	2140.7	2322.9	1322.9	190.7	163.4	137.9	208.0	178.3	148.6
SPAN= 075	3083.1	2590.7	2181.5	2368.5	1344.0	191.9	164.5	138.4	209.3	179.5	149.6
SPAN= 076	3138.9	2637.6	2222.3	2414.1	1365.1	193.1	165.5	138.8	210.6	180.6	150.5
SPAN= 077	3194.7	2684.5	2263.0	2459.6	1386.1	194.3	166.5	139.3	211.9	181.6	151.4
SPAN= 078	3250.4	2731.3	2303.6	2505.0	1407.1	195.4	167.5	139.7	213.1	182.7	152.2
SPAN= 079	3306.0	2778.0	2344.2	2550.4	1428.1	196.5	168.4	140.4	214.3	183.7	153.1
SPAN= 080	3361.5	2824.7	2386.8	2595.7	1449.0	197.5	169.3	141.1	215.4	184.6	153.9
SPAN= 081	3417.0	2871.3	2429.6	2641.0	1469.9	198.6	170.2	141.9	216.5	185.6	154.6
SPAN= 082	3472.4	2917.8	2472.4	2686.2	1490.8	199.6	171.1	142.6	217.5	186.4	155.4
SPAN= 083	3527.6	2964.2	2515.1	2731.3	1511.7	200.5	171.9	143.3	218.5	187.3	156.1
SPAN= 084	3582.8	3010.6	2557.8	2776.3	1532.5	201.5	172.7	143.9	219.5	188.2	156.8
SPAN= 085	3638.0	3069.7	2600.3	2821.3	1553.3	202.4	173.5	144.6	220.4	189.0	157.5
SPAN= 086	3693.0	3129.1	2642.9	2866.3	1574.0	203.3	174.3	145.2	221.4	189.7	158.1
SPAN= 087	3748.0	3188.4	2685.4	2911.2	1594.8	204.1	175.0	145.8	222.2	190.5	158.8
SPAN= 088	3802.9	3247.6	2727.8	2956.0	1615.5	205.0	175.7	146.4	223.1	191.2	159.4
SPAN= 089	3857.8	3306.7	2770.1	3000.7	1636.2	205.8	176.4	147.0	223.9	192.0	160.0
SPAN= 090	3926.7	3365.8	2812.4	3045.5	1656.9	206.6	177.1	147.6	224.7	192.6	160.5
SPAN= 091	3995.5	3424.7	2854.7	3090.1	1677.5	207.4	177.8	148.1	225.5	193.3	161.1
SPAN= 092	4064.2	3483.6	2903.0	3134.7	1698.1	208.1	178.4	148.7	226.3	193.9	161.6
SPAN= 093	4132.8	3542.4	2952.0	3179.2	1718.7	208.9	179.0	149.2	227.0	194.6	162.2
SPAN= 094	4201.3	3601.1	3001.0	3223.7	1739.3	209.7	179.6	149.7	227.7	195.2	162.7
SPAN= 095	4270.0	3660.0	3050.0	3268.2	1759.9	210.5	180.2	150.2	229.0	195.8	163.2
SPAN= 096	4338.7	3718.9	3099.1	3312.6	1780.5	211.2	180.8	150.7	230.4	196.6	163.6
SPAN= 097	4407.2	3777.6	3148.0	3356.9	1801.0	212.0	181.4	151.2	231.8	197.7	164.1
SPAN= 098	4475.7	3836.3	3197.0	3401.2	1821.5	212.7	181.9	151.6	233.1	198.9	164.6
SPAN= 099	4544.1	3894.9	3245.8	3445.4	1842.0	213.9	182.5	152.1	234.4	200.0	165.5
SPAN= 100	4612.4	3953.5	3294.6	3489.6	1862.5	215.1	183.5	152.5	235.7	201.0	166.4
SPAN= 101	4680.6	4012.0	3343.3	3533.7	1882.9	216.2	184.4	152.9	236.9	202.1	167.3
SPAN= 102	4748.8	4070.4	3392.0	3577.8	1903.3	217.3	185.4	153.4	238.1	203.1	168.1
SPAN= 103	4816.8	4128.7	3440.6	3621.8	1923.8	218.4	186.3	154.2	239.3	204.1	168.9
SPAN= 104	4884.8	4187.0	3489.2	3665.8	1944.1	219.4	187.2	154.9	240.4	205.1	169.7
SPAN= 105	4952.7	4245.2	3537.7	3709.7	1964.5	220.5	188.1	155.6	241.5	206.0	170.5
SPAN= 106	5020.5	4303.3	3586.1	3753.6	1984.8	221.5	188.9	156.4	242.6	206.9	171.3
SPAN= 107	5088.3	4361.4	3634.5	3797.5	2005.2	222.4	189.7	157.0	243.6	207.8	172.0
SPAN= 108	5156.0	4419.4	3682.9	3841.3	2025.5	223.4	190.6	157.7	244.7	208.7	172.7
SPAN= 109	5223.6	4477.4	3731.2	3885.0	2045.7	224.3	191.4	158.4	245.7	209.6	173.4
SPAN= 110	5291.1	4535.2	3779.4	3928.8	2066.0	225.3	192.2	159.0	246.6	210.4	174.1
SPAN= 111	5358.5	4593.1	3827.6	3972.4	2086.3	226.2	192.9	159.7	247.6	211.2	174.8
SPAN= 112	5425.9	4650.8	3875.7	4016.1	2106.5	227.0	193.7	160.3	248.5	212.0	175.4
SPAN= 113	5493.2	4708.5	3923.8	4059.6	2126.7	227.9	194.4	160.9	249.4	212.7	176.1
SPAN= 114	5560.5	4766.1	3971.8	4103.2	2146.9	228.7	195.1	161.5	250.3	213.5	176.7
SPAN= 115	5627.6	4823.7	4019.8	4146.7	2167.0	229.6	195.8	162.1	251.1	214.2	177.3
SPAN= 116	5695.6	4881.4	4067.9	4190.2	2187.2	230.4	196.5	162.7	252.0	214.9	177.9
SPAN= 117	5771.4	4939.1	4115.9	4233.6	2207.3	231.2	197.2	163.2	252.8	215.6	178.5
SPAN= 118	5851.9	4996.7	4164.0	4277.0	2227.4	231.9	197.9	163.8	253.6	216.3	179.0
SPAN= 119	5932.3	5059.9	4211.9	4320.3	2247.5	232.7	198.5	164.3	254.4	217.0	179.6
SPAN= 120	6012.6	5128.4	4259.9	4363.6	2267.6	233.5	199.1	164.8	255.1	217.6	180.1
SPAN= 121	6092.9	5196.9	4307.7	4406.9	2287.7	234.2	199.8	165.3	255.9	218.3	180.6
SPAN= 122	6173.0	5265.2	4357.5	4450.1	2307.7	234.9	200.4	165.8	256.6	218.9	181.2
SPAN= 123	6253.1	5333.5	4414.0	4493.3	2327.7	235.6	201.0	166.3	257.3	219.5	181.7
SPAN= 124	6333.1	5401.8	4470.5	4536.4	2347.7	236.3	201.6	166.8	258.0	220.1	182.1
SPAN= 125	6413.0	5469.9	4526.9	4579.5	2367.7	237.0	202.1	167.3	258.7	220.7	182.6
SPAN= 126	6492.8	5538.0	4583.2	4622.6	2387.7	237.6	202.7	167.8	259.3	221.2	183.1
SPAN= 127	6572.6	5606.1	4639.5	4665.7	2407.7	238.3	203.2	168.2	260.0	221.8	183.5
SPAN= 128	6652.3	5674.0	4695.8	4708.7	2427.6	238.9	203.8	168.7	260.6	222.3	184.0
SPAN= 129	6731.9	5741.9	4752.0	4751.6	2447.6	239.5	204.3	169.1	261.2	222.8	184.4
SPAN= 130	6811.4	5809.8	4808.1	4794.6	2467.5	240.1	204.8	169.5	261.8	223.3	184.9
SPAN= 131	6890.9	5877.5	4864.2	4837.5	2487.4	240.7	205.4	170.0	262.4	223.8	185.3
SPAN= 132	6970.3	5945.2	4920.2	4880.4	2507.3	241.3	205.9	170.4	263.0	224.3	185.7
SPAN= 133	7049.6	6012.9	4976.2	4923.2	2527.1	241.9	206.3	170.8	263.6	224.8	186.1
SPAN= 134	7128.8	6080.5	5032.1	4966.0	2547.0	242.5	206.8	171.2	264.1	225.3	186.5
SPAN= 135	7208.2	6148.2	5088.2	5008.8	2566.8	243.0	207.3	171.6	264.7	225.8	186.8
SPAN= 136	7287.7	6216.0	5144.3	5051.5	2586.7	243.6	207.8	172.0	265.2	226.2	187.2
SPAN= 137	7367.0	6283.6	5200.3	5094.2	2606.5	244.1	208.2	172.3	265.7	226.6	187.6
SPAN= 138	7446.3	6351.2	5256.2	5136.9	2626.3	244.6	208.7	172.7	266.2	227.1	187.9
SPAN= 139	7525.5	6418.8	5312.1	5179.5	2646.1	245.2	209.1	173.1	266.7	227.5	188.3
SPAN= 140	7604.6	6486.3	5368.0	5222.1	2665.8	245.7	209.6	173.4	267.2	227.9	188.6
SPAN= 141	7683.7	6553.7	5423.8	5264.7	2685.6	246.2	210.0	173.8	267.7	228.3	189.0
SPAN= 142	7762.7	6621.1	5479.6	5307.3	2705.3	246.7	210.4	174.1	268.1	228.7	189.3
SPAN= 143	7841.6	6688.5	5535.3	5349.8	2725.1	247.1	210.8	174.5	268.6	229.1	189.6
SPAN= 144	7920.5	6755.7	5591.0	5392.3	2744.8	247.6	211.2	174.8	269.0	229.5	189.9
SPAN= 145	7999.3	6823.0	5646.6	5434.7	2764.6	248.1	211.6	175.1	269.5	229.8	190.2

APPENDIX F – CLSABC2U.TXT file used by BridgeOV

SPAN= 146	8078.1	6890.1	5702.2	5477.2	2798.1	248.5	212.0	175.5	269.9	230.2	190.5
SPAN= 147	8156.8	6957.3	5757.7	5519.6	2829.6	249.0	212.4	175.8	270.3	230.6	190.8
SPAN= 148	8235.4	7024.3	5813.2	5561.9	2861.2	249.4	212.8	176.1	270.7	230.9	191.1
SPAN= 149	8314.0	7091.3	5868.7	5604.3	2893.0	249.9	213.1	176.4	271.1	231.3	191.4
SPAN= 150	8392.5	7158.3	5924.1	5646.6	2925.0	250.3	213.5	176.7	271.5	231.6	191.7
SPAN= 151	8470.9	7225.2	5979.5	5688.9	2957.1	250.7	213.9	177.0	271.9	231.9	192.0
SPAN= 152	8549.3	7292.1	6034.8	5731.2	2989.4	251.1	214.2	177.3	272.3	232.2	192.2
SPAN= 153	8627.7	7358.9	6090.1	5773.4	3021.9	251.5	214.6	177.6	272.6	232.6	192.5
SPAN= 154	8705.9	7425.7	6145.4	5815.6	3054.5	251.9	214.9	177.9	273.0	232.9	192.7
SPAN= 155	8784.2	7492.4	6200.6	5857.8	3087.3	252.3	215.2	178.1	273.4	233.2	193.0
SPAN= 156	8862.3	7559.1	6255.8	5900.0	3120.2	252.7	215.6	178.4	273.7	233.5	193.2
SPAN= 157	8940.4	7625.7	6310.9	5942.1	3153.3	253.1	215.9	178.7	274.0	233.8	193.5
SPAN= 158	9018.5	7692.3	6366.0	5984.2	3186.6	253.5	216.2	179.0	274.4	234.0	193.7
SPAN= 159	9096.5	7758.8	6421.1	6026.3	3220.0	253.8	216.5	179.2	274.7	234.3	193.9
SPAN= 160	9174.4	7825.3	6476.1	6068.4	3253.6	254.2	216.8	179.5	275.0	234.6	194.2
SPAN= 161	9252.3	7891.7	6531.1	6110.4	3287.4	254.6	217.1	179.7	275.3	234.9	194.4
SPAN= 162	9330.2	7958.1	6586.0	6152.4	3321.3	254.9	217.4	180.0	275.6	235.1	194.6
SPAN= 163	9408.0	8024.5	6641.0	6194.4	3355.4	255.3	217.7	180.2	275.9	235.4	194.8
SPAN= 164	9485.7	8090.8	6695.8	6236.3	3389.6	255.6	218.0	180.5	276.2	235.6	195.0
SPAN= 165	9563.4	8157.0	6750.7	6278.3	3424.0	255.9	218.3	180.7	276.5	235.9	195.2
SPAN= 166	9641.0	8223.3	6805.5	6320.2	3458.6	256.3	218.6	180.9	276.8	236.1	195.4
SPAN= 167	9718.6	8289.4	6860.2	6362.1	3493.3	256.6	218.9	181.2	277.1	236.4	195.6
SPAN= 168	9796.2	8355.6	6915.0	6404.0	3528.2	256.9	219.2	181.4	277.4	236.6	195.8
SPAN= 169	9873.7	8421.7	6969.7	6445.8	3563.3	257.2	219.4	181.6	277.6	236.8	196.0
SPAN= 170	9951.1	8487.7	7024.3	6487.6	3598.5	257.5	219.7	181.8	277.9	237.1	196.2
SPAN= 171	10028.5	8553.7	7079.0	6529.4	3633.9	257.9	219.9	182.0	278.2	237.3	196.4
SPAN= 172	10105.9	8619.7	7133.6	6571.2	3669.5	258.2	220.2	182.3	278.4	237.5	196.6
SPAN= 173	10183.3	8685.7	7188.2	6613.0	3705.2	258.4	220.5	182.5	278.7	237.7	196.7
SPAN= 174	10260.7	8751.8	7242.9	6654.7	3741.0	258.7	220.7	182.7	278.9	237.9	196.9
SPAN= 175	10338.2	8817.9	7297.6	6696.4	3777.1	259.0	221.0	182.9	279.2	238.1	197.1
SPAN= 176	10415.6	8883.9	7352.2	6738.1	3813.3	259.3	221.2	183.1	279.4	238.3	197.2
SPAN= 177	10492.9	8949.9	7406.8	6779.8	3849.6	259.6	221.4	183.3	279.6	238.5	197.4
SPAN= 178	10570.2	9015.8	7461.4	6821.4	3886.2	259.9	221.7	183.5	279.9	238.7	197.6
SPAN= 179	10647.5	9081.7	7515.9	6863.0	3922.9	260.1	221.9	183.7	280.1	238.9	197.7
SPAN= 180	10724.7	9147.6	7570.4	6904.7	3959.7	260.4	222.1	183.8	280.3	239.1	197.9
SPAN= 181	10801.9	9213.4	7624.9	6946.2	3996.7	260.7	222.4	184.0	280.5	239.3	198.0
SPAN= 182	10879.0	9279.2	7679.3	6987.8	4033.9	260.9	222.6	184.2	280.7	239.5	198.2
SPAN= 183	10956.1	9344.9	7733.8	7029.4	4071.2	261.2	222.8	184.4	280.9	239.6	198.3
SPAN= 184	11033.2	9410.7	7788.1	7070.9	4108.7	261.4	223.0	184.6	281.1	239.8	198.5
SPAN= 185	11110.2	9476.3	7842.5	7112.4	4146.4	261.7	223.2	184.8	281.3	240.0	198.6
SPAN= 186	11187.1	9542.0	7896.8	7153.9	4184.2	261.9	223.4	184.9	281.5	240.1	198.8
SPAN= 187	11264.1	9607.6	7951.1	7195.4	4222.2	262.2	223.6	185.1	281.7	240.3	198.9
SPAN= 188	11340.9	9673.2	8005.4	7236.8	4260.3	262.4	223.8	185.3	281.9	240.5	199.0
SPAN= 189	11417.8	9738.7	8059.6	7278.3	4298.7	262.7	224.0	185.4	282.1	240.6	199.2
SPAN= 190	11494.6	9804.2	8113.9	7319.7	4337.1	262.9	224.2	185.6	282.3	240.8	199.3
SPAN= 191	11571.3	9869.7	8168.0	7361.1	4375.8	263.1	224.4	185.8	282.5	240.9	199.4
SPAN= 192	11648.1	9935.1	8222.2	7402.4	4414.6	263.3	224.6	185.9	282.6	241.1	199.5
SPAN= 193	11724.8	10000.5	8276.3	7443.8	4453.5	263.6	224.8	186.1	282.8	241.2	199.7
SPAN= 194	11801.4	10065.9	8330.4	7485.2	4492.6	263.8	225.0	186.2	283.0	241.4	199.8
SPAN= 195	11878.0	10131.3	8384.5	7526.5	4531.9	264.0	225.2	186.4	283.2	241.5	199.9
SPAN= 196	11954.6	10196.6	8438.6	7567.8	4571.4	264.2	225.4	186.5	283.3	241.7	200.0
SPAN= 197	12031.1	10261.9	8492.6	7609.1	4611.0	264.4	225.6	186.7	283.5	241.8	200.1
SPAN= 198	12107.6	10327.1	8546.6	7650.4	4650.7	264.6	225.7	186.8	283.6	241.9	200.2
SPAN= 199	12184.1	10392.3	8600.6	7691.6	4690.7	264.8	225.9	187.0	283.8	242.1	200.4
SPAN= 200	12260.5	10457.5	8654.5	7732.9	4730.8	265.0	226.1	187.1	283.9	242.2	200.5
SPAN= 201	12336.9	10522.7	8708.4	7773.9	4771.0	265.2	226.2	187.3	284.1	242.3	200.6
SPAN= 202	12413.2	10587.8	8762.3	7773.9	4811.4	265.4	226.4	187.4	284.2	242.5	200.7
SPAN= 203	12489.6	10652.9	8816.2	7773.9	4852.0	265.6	226.6	187.5	284.4	242.6	200.8
SPAN= 204	12565.8	10717.9	8870.0	7773.9	4892.8	265.8	226.7	187.7	284.5	242.7	200.9
SPAN= 205	12642.1	10783.0	8923.9	7773.9	4933.7	266.0	226.9	187.8	284.7	242.8	201.0
SPAN= 206	12718.3	10848.0	8977.7	7773.9	4974.7	266.2	227.1	187.9	284.8	242.9	201.1
SPAN= 207	12794.5	10913.0	9031.4	7773.9	5016.0	266.4	227.2	188.1	285.0	243.1	201.2
SPAN= 208	12870.6	10977.9	9085.2	7773.9	5057.3	266.6	227.4	188.2	285.1	243.2	201.3
SPAN= 209	12946.7	11042.8	9138.9	7773.9	5098.9	266.7	227.5	188.3	285.2	243.3	201.4
SPAN= 210	13022.8	11107.7	9192.6	7773.9	5140.6	266.9	227.7	188.4	285.3	243.4	201.4
SPAN= 211	13098.9	11172.6	9246.3	7773.9	5182.5	267.1	227.8	188.6	285.5	243.5	201.5
SPAN= 212	13174.9	11237.4	9300.0	7773.9	5224.5	267.3	228.0	188.7	285.6	243.6	201.6
SPAN= 213	13250.9	11302.2	9353.6	7773.9	5266.7	267.4	228.1	188.8	285.7	243.7	201.7
SPAN= 214	13326.8	11367.0	9407.2	7773.9	5309.1	267.6	228.3	188.9	285.8	243.8	201.8
SPAN= 215	13402.7	11431.8	9460.8	7773.9	5351.6	267.8	228.4	189.0	286.0	243.9	201.9
SPAN= 216	13478.6	11496.5	9514.4	7773.9	5394.3	267.9	228.6	189.2	286.1	244.0	202.0
SPAN= 217	13554.5	11561.2	9567.9	7773.9	5437.1	268.1	228.7	189.3	286.2	244.1	202.0
SPAN= 218	13630.3	11625.9	9621.4	7773.9	5480.1	268.3	228.8	189.4	286.3	244.2	202.1
SPAN= 219	13706.1	11690.5	9674.9	7773.9	5523.3	268.4	229.0	189.5	286.4	244.3	202.2
SPAN= 220	13781.9	11755.1	9728.4	7773.9	5566.6	268.6	229.1	189.6	286.5	244.4	202.3
SPAN= 221	13857.6	11819.7	9781.9	7773.9	5610.1	268.7	229.2	189.7	286.6	244.5	202.4
SPAN= 222	13933.3	11884.3	9835.3	7773.9	5653.8	268.9	229.4	189.8	286.7	244.6	202.4
SPAN= 223	14009.0	11948.9	9888.7	7773.9	5697.6	269.0	229.5	189.9	286.8	244.7	202.5
SPAN= 224	14084.6	12013.4	9942.1	7773.9	5741.6	269.2	229.6	190.0	286.9	244.8	202.6
SPAN= 225	14160.3	12077.9	9995.5	7773.9	5785.7	269.3	229.7	190.1	287.0	244.8	202.6
SPAN= 226	14235.8	12142.4	10048.9	7773.9	5830.0	269.5	229.9	190.3	287.1	244.9	202.7

APPENDIX F – CLSABC2U.TXT file used by BridgeOV

SPAN= 227	14311.4	12206.8	10102.2	7732.9	5874.5	269.6	230.0	190.4	287.2	245.0	202.8
SPAN= 228	14386.9	12271.2	10155.5	7732.9	5919.1	269.8	230.1	190.5	287.3	245.1	202.9
SPAN= 229	14462.4	12335.6	10208.8	7732.9	5963.9	269.9	230.2	190.6	287.4	245.2	202.9
SPAN= 230	14537.9	12400.0	10262.1	7732.9	6008.8	270.0	230.3	190.7	287.5	245.3	203.0
SPAN= 231	14613.4	12464.4	10315.4	7732.9	6053.9	270.2	230.5	190.7	287.6	245.3	203.0
SPAN= 232	14688.8	12528.7	10368.6	7732.9	6099.2	270.3	230.6	190.8	287.7	245.4	203.1
SPAN= 233	14764.2	12593.0	10421.8	7732.9	6144.6	270.5	230.7	190.9	287.8	245.5	203.2
SPAN= 234	14839.6	12657.3	10475.0	7732.9	6190.2	270.6	230.8	191.0	287.9	245.6	203.2
SPAN= 235	14914.9	12721.5	10528.2	7732.9	6236.0	270.7	230.9	191.1	288.0	245.6	203.3
SPAN= 236	14990.2	12785.8	10581.4	7732.9	6281.9	270.8	231.0	191.2	288.0	245.7	203.4
SPAN= 237	15065.5	12850.0	10634.5	7732.9	6328.0	271.0	231.1	191.3	288.1	245.8	203.4
SPAN= 238	15140.8	12914.2	10687.6	7732.9	6374.2	271.1	231.2	191.4	288.2	245.8	203.5
SPAN= 239	15216.0	12978.4	10740.7	7732.9	6420.6	271.2	231.4	191.5	288.3	245.9	203.5
SPAN= 240	15291.2	13042.5	10793.8	7732.9	6467.2	271.3	231.5	191.6	288.4	246.0	203.6
SPAN= 241	15366.4	13106.7	10846.9	7732.9	6513.9	271.5	231.6	191.7	288.4	246.0	203.6
SPAN= 242	15441.6	13170.8	10900.0	7732.9	6560.8	271.6	231.7	191.7	288.5	246.1	203.7
SPAN= 243	15516.9	13235.0	10953.2	7732.9	6607.8	271.7	231.8	191.8	288.6	246.2	203.7
SPAN= 244	15592.2	13299.2	11006.3	7732.9	6655.0	271.8	231.9	191.9	288.7	246.2	203.8
SPAN= 245	15667.4	13363.4	11059.4	7732.9	6702.4	271.9	232.0	192.0	288.7	246.3	203.8
SPAN= 246	15742.7	13427.6	11112.5	7732.9	6749.9	272.1	232.1	192.1	288.8	246.4	203.9
SPAN= 247	15817.9	13491.7	11165.6	7732.9	6797.6	272.2	232.2	192.2	288.9	246.4	203.9
SPAN= 248	15893.0	13555.8	11218.6	7732.9	6845.5	272.3	232.3	192.2	288.9	246.5	204.0
SPAN= 249	15968.2	13619.9	11271.7	7732.9	6893.5	272.4	232.4	192.3	289.0	246.5	204.0
SPAN= 250	16043.3	13684.0	11324.7	7732.9	6941.7	272.5	232.4	192.4	289.1	246.6	204.1

Appendix G – BridgeOV-Virtis Application Programming Interface (API) interface

There is a wrapper class in C# that is the interface that MiTRIP would use to invoke bridge permit applications. A description of the wrapper classes, the input required, and the output generated are provided in the following sections.

The wrapper class functions, the input required for the functions, and output produced by the functions are described in the following sections. In order to access these classes, Virtis must be fully installed on the machine being used. The classes are available in the

Wrapper class functions

The wrapper class for the Michigan program has three basic functions **Start**, **End**, and **ProcessRequest**. The sample code show below starts a session and performs a permit and then ends the session.

Sample Code:

```
SessionReturnCode retCode = Session.Instance.Start("virtis", "virtis", "Virtis62s");
```

```
Session.Instance.ProcessRequest(sInputFileName, sOutputFileName, StatusFileName,  
ref sErrorMessages, ref sWarningMessages);
```

```
Session.Instance.End();
```

The Start() and End() function calls can be moved out so that Start is called when the application starts and End is called when the application exits, and multiple ProcessPermitRequest function calls could be invoked while the session is active.

A detailed description of these functions along with their passed parameters is provided in the following sections.

SessionReturnCode Start((string sUsername, string sPassword, string sDataSource)

The Start function initializes the VirtisOpis API and connects to the specified Virtis Database. This function must be called first. The syntax for the call is shown below.

Example:

```
SessionReturnCode retCode = Session.Instance.Start("virtis", "virtis", "Virtis62s");
```

Passed Parameters

Parameter	Type	Description
sUsername	string	Virtis username
sPassword	string	Virtis password
sDataSource	string	ODBC Virtis database name

Return Codes

Code	Code	Description
ABW_SUCCESS	0,	Virtis ran successfully.
ABW_SYSTEM_ERROR	-1,	
ABW_E_DBLOGIN	-2,	
ABW_E_INITIALIZATION	-3,	
ABW_E_SESSION_ACTIVE	-4,	
ABW_E_NOT_VALID_USER	-5,	
ABW_E_INCORRECT_DB_SCHEMA	-6,	
ABW_E_UNABLE_TO_VERIFY_DB_SCHEMA	-7,	
ABW_E_UNABLE_GRANT_WRITE_PRIV	-8,	
ABW_E_INCORRECT_DB_PATCH_LEVEL	-9,	
ABW_E_INCORRECT_DB_BUILD_VERSION	-10,	

bool ProcessRequest(string sInputFileName, string sOutputFileName, string sStatusFileName, ref string sErrorMessages, ref string sWarningMessages, ref object objtextbx)

This function processes a permit request file. The permit request file is an XML file and is described in detail in a subsequent section. The output of the process is also an XML file which provides a list of the results for each bridge analyzed for each vehicle. The output file is described in detail in a later section.

Passed Parameters

Parameter	Type	Description
sInputFileName	string	XML input file listing the bridges to be analyzed and the vehicles to use to analyze them. Described in more detail in a later section
sOutputFileName	string	XML output file listing the results of the Virtis analysis/ BridgeOV run. Described in more detail in later sections
sStatusFileName	string	XML listing the status of the run. Described in more detail in later sections
sErrorMessages	ref string	String containing any error messages encountered when running Virtis
sWarningMessages	ref string	String containing any warning messages encountered when running Virtis
Objtextbx	Object	If the function is going to return messages while running each bridge, place a Forms.TextBox object in this parameter. If no messages are to be returned, as would be the case when running from MiTRIP, pass a null for this parameter.

APPENDIX G – BridgeOV-Virtis API

Return Codes

Code	Description
True	Virtis ran successfully.
False	Virtis did not run successfully.

API Input File

This section provides a detail description of the API input file that is required to run BridgeOV/Virtis in the patch mode. This file would be generated by the calling program and the name/location of the file passed through the API as described in the calls provided in the previous section.

Sample input file

For the sample application (BridgeOV-Virtis) described in this appendix the API input file has an *.mdr extension but is in XML format. Below is a sample file.

```
<?xml version="1.0" encoding="UTF-8"?>
<routing>
  <file_version>1.0</file_version>
  <permit application number>6857asdf </permit_application_number>
  <requested_by>John Doe</requested_by>
  <application timestamp>12:42
  </application_timestamp>
  <structural_analysis_type>Standard</structural_analysis_type>
  <min allowable rating factor>1.0</min allowable_rating_factor>
  <max span_length_factor>1.2</max_span_length_factor >
  <route>
    <bridge list>
<!-- Class A - Virtis - S flag -->
      <bridge>
        <bridge_id>82182023000S270</bridge_id>
        <route id>00006</route id>
        <travel_direction>0</travel_direction>
        <abcd category>A</abcd category>
        <r_or_s_flag>S</r_or_s_flag>
        <nbi_max_span_length>69.69</nbi_max_span_length>
      </bridge>
<!-- Class B - Virtis - S flag -->
      <bridge>
        <bridge_id>82182023000S270</bridge_id>
        <route id>00006</route id>
        <travel_direction>0</travel_direction>
        <abcd category>B</abcd category>
        <r_or_s_flag>S</r_or_s_flag>
        <nbi_max_span_length>69.69</nbi_max_span_length>
      </bridge>

<!-- Class F - BridgeOV - S flag - Short 5' span -->
      <bridge>
        <bridge_id>82182023000S270</bridge_id>
        <route id>00006</route id>
        <travel_direction>0</travel_direction>
        <abcd_category>F</abcd_category>
        <r_or_s_flag>S</r_or_s_flag>
        <nbi_max_span_length>5</nbi_max_span_length>
      </bridge>
<!-- Class G - BridgeOV - S flag - Short 5' span -->
      <bridge>
```

APPENDIX G – BridgeOV-Virtis API

```
<bridge_id>82182023000S270</bridge_id>
<route_id>00006</route_id>
<travel_direction>0</travel_direction>
<abcd_category>G</abcd_category>
<r_or_s_flag>S</r_or_s_flag>
<nbi_max_span_length>85</nbi_max_span_length>
</bridge>
<!-- Class C - Virtis - R flag -->
<bridge>
  <bridge_id>junk bridge C</bridge_id>
  <route_id>00006</route_id>
  <travel_direction>0</travel_direction>
  <abcd_category>C</abcd_category>
  <r_or_s_flag>R</r_or_s_flag>
  <nbi_max_span_length>69.69</nbi_max_span_length>
</bridge>
<!-- Class X - invalid Class -->
<bridge>
  <bridge_id>junk bridge C</bridge_id>
  <route_id>00006</route_id>
  <travel_direction>0</travel_direction>
  <abcd_category>X</abcd_category>
  <r_or_s_flag>R</r_or_s_flag>
  <nbi_max_span_length>69.69</nbi_max_span_length>
</bridge>
<!-- Incomplete bridge in database - Should run successfully in BridgeOV -->
<bridge>
  <bridge_id>MDOT-Failed</bridge_id>
  <route_id>00006</route_id>
  <travel_direction>0</travel_direction>
  <abcd_category>A</abcd_category>
  <r_or_s_flag>R</r_or_s_flag>
  <nbi_max_span_length>69.69</nbi_max_span_length>
</bridge>
</bridge_list>
</route>
<routing_vehicle_list>
  <vehicle_description>
    <name>Test Vehicle</name>
    <controlling_rating_level>Operating</controlling_rating_level>
    <single_lane_ind>FALSE</single_lane_ind>
    <impact>1.00</impact>
    <units>
      <weight_unit>kip</weight_unit>
      <wheel_contact_width_unit>inch</wheel_contact_width_unit>
      <axle_spacing_unit>foot</axle_spacing_unit>
    </units>
    <axle_list>
      <axle_description>
        <weight>8.000</weight>
        <wheel_contact_width>20.000</wheel_contact_width>
        <gage_distance>8.0</gage_distance>
      </axle_description>
      <axle_description>
        <weight>32.000</weight>
        <wheel_contact_width>20.000</wheel_contact_width>
        <axle_spacing>14.000</axle_spacing>
        <gage_distance>10.0</gage_distance>
      </axle_description>
      <axle_description>
        <weight>39.000</weight>
        <wheel_contact_width>20.000</wheel_contact_width>
        <axle_spacing>14</axle_spacing>
        <gage_distance>9.0</gage_distance>
      </axle_description>
    </axle_list>
  </vehicle_description>
</routing_vehicle_list>
</routing>
```

Input File Format

The permit request file format has a similar format as Virtis application’s routing request file format. It is an XML file conforming to the following specifications. It is assumed that the user has an understanding of XML syntax so an explanation of XML is not provided here. Descriptions of individual wheels composing of an axle are only supported for non-standard gage vehicle.

XML Tag	Description
<routing>	Indicates the beginning of the routing information
<file_version>	Indicates the version of the routing request file. Should be 1.0.
<permit_application_number>	Permit application number for tracking purposes
<requested_by>	Name of person submitting the routing request file
<application_timestamp>	Time that the routing request file was created
<structural_analysis_type>	Type of structural analysis. Should be either "StandardGage" or "NonStandardGage".
<min_allowable_rating_factor>	Minimum allowable rating factor. Default is 1.00.
<max_span_length_factor>	This value is multiplied by the nbi_max_span_length factor to set the upper limit of span length for BridgeOV runs.
<comment>	Indicates start of comments

APPENDIX G – BridgeOV-Virtis API

XML Tag	Description
<route>	Indicates start of route
<bridge_list>	Indicates start of list of bridges on route
<bridge>	Indicates start of data for a bridge on the route
<bridge_id>	Agency bridge ID
<route_id>	Route ID
<travel_direction>	Travel Direction. Default value is 0. -1/down/down milepost = Down Milepost 1/up/up milepost = Up Milepost 0 = Not Specified

APPENDIX G – BridgeOV-Virtis API

XML Tag	Description
<abcd_cateogry>	<p>This item is specific to Michigan DOT. This is the MDOT specific NBI code Item 193 Overload class.</p> <p>The item can have the following options:</p> <p>A – Run BridgeOV always (i.e. don't try to run Virtis). Use Class A</p> <p>B – Run BridgeOV always (i.e. don't try to run Virtis) Use Class B.</p> <p>C – Run BridgeOV always (i.e. don't try to run Virtis) Use Class C.</p> <p>D - Fail</p> <p>F – Run Virtis. If bridge not present in Virtis run BridgeOV with Class A.</p> <p>G – Run Virtis. If bridge not present in Virtis run BridgeOV with Class B.</p> <p>H – Run Virtis. If bridge not present in Virtis run BridgeOV with Class C.</p>
<r_or_s_flag>	<p>This can be any of the following:</p> <p>R – If running BridgeOV use the standard 8' axle width (i.e. no factoring the axle loads).</p> <p>Blank – Use the actual gage with axle loads that were reduced (increased) to account for gage width. In this case each axle load is divided by $(\text{gage width} + 8')/16.0$</p> <p>This is from the original BridgeOV program.</p> <p>S – If the bridge is a Class B or C and any axle exceeds 38,000 pounds, fail the bridge</p>

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XML Tag	Description
<nbi_max_span_length>	If the bridge is analyzed using BridgeOV, use the maximum span length * max_span_length_factor as the upper span length limit for BridgeOV
<routing_vehicle_list>	Indicates start of list of vehicles for analysis
<vehicle_description>	Indicates start of data for a vehicle
<adjacent_lane_vehicle_description>	Indicates start of data for a adjacent lane vehicle
<name>	Name of vehicle
<vehicle_gage_type>	Type of vehicle gage. Should be either "StandardGage" or "NonStandardGage".
<controlling_rating_level>	Indicates rating factor to be checked to determine pass or fail status of rating. Should be either "Inventory" or "Operating".
<single_lane_ind>	Indicates if single lane distribution factors should be used in analysis. Should be either "TRUE" or "FALSE".
<bov_lfr_lrfr>	Enter 'LFR' or 'LRFR' to set the method to run BridgeOV. This value is not used by Virtis.
<impact>	User defined impact value for the vehicle.
<units>	Indicates start of list of units for the vehicle
<weight_unit>	Unit for the axle or wheel weight. Should be "kip", "pound", "kilonewton", or "newton".

APPENDIX G – BridgeOV-Virtis API

XML Tag	Description
<gage_distance_unit>	Unit for the gage distance. Should be "foot", "inch", "meter", or "millimeter".
<wheel_contact_width_unit>	Unit for the wheel contact width. Should be "foot", "inch", "meter", or "millimeter".
<dist_first_wheel_unit>	Unit for the distance to first wheel. Should be "foot", "inch", "meter", or "millimeter".
<axle_spacing_unit>	Unit for the axle spacing. Should be "foot", "inch", "meter", or "millimeter".
<wheel_spacing_unit>	Unit for the wheel spacing. Should be "foot", "inch", "meter", or "millimeter".
<axle_list>	Indicates start of list of axles belonging to the vehicle
<axle_description>	Indicates start of data for an axle
<weight>	Weight of the axle
<gage_distance>	Gage distance of the axle
<wheel_contact_width>	Wheel contact width
<dist_first_wheel>	Distance from the centerline of the vehicle to the first wheel of the axle
<axle_spacing>	Constant spacing to this axle from the preceding axle
<minimum_axle_spacing>	Minimum spacing to this axle from the preceding

APPENDIX G – BridgeOV-Virtis API

XML Tag	Description
	axle. Not required if constant axle spacing was specified.
<maximum_axle_spacing>	Maximum spacing to this axle from the preceding axle. Not required if constant axle spacing was specified.
<wheel_list>	Indicates start of list of wheels belonging to the axle
<wheel_description>	Indicates start of data for a wheel
<weight>	Weight of the wheel
<wheel_contact_width>	Wheel contact width
<wheel_spacing>	Spacing to this wheel from the preceding wheel

API Output File

This section provides a description of the XML output file produced by the API and the accompanying XSL stylesheet that is generated. The XML file can be used with the stylesheet for the final report, or the XML file and the data contained it can be parsed and used as needed.

Sample Output File (XML/XSL)

The output file format is also in XML and has an accompanying XSL stylesheet for viewing. The file naming convention for the output XML file and XSL stylesheet is as shown below:

'ROOT'Output_SUM.XML

'ROOT'Output_SUM.XSL

Where:

ROOT - Prefix of the file name. e.g. if the input file name is 'Sample.XML' the output XML file is 'SampleOutput_SUM.XML' and 'SampleOutput_SUM.XML'.

The raw XML output is shown below.

```
<?xml version="1.0" encoding="UTF-8"?>
<?xml-stylesheet type="text/xsl" href="C:\Proj\Michigan-DOT\Dev\mml\TestFiles-
XML\TestSuite\SmallTestSampleOutput_SUM.XSL"?>
<MDOTrouting Output>
  <permit_application_number>6857asdf </permit_application_number>
  <requested_by>John Doe</requested_by>
  <application_timestamp>10/14/2012 5:34:59 PM</application_timestamp>
  <structural_analysis_type>Standard</structural_analysis_type>
  <max_span_length_factor>1.2</max_span_length_factor>
  <results>
    <bridge>
      <controls>TRUE</controls>
      <vehicle_name>Test Vehicle</vehicle_name>
      <rating_level>Operating</rating_level>
      <bridge_id>82182023000S270</bridge_id>
      <route_id>00006</route_id>
      <pass_fail>PASS</pass_fail>
      <process>Virtis</process>
      <pass_fail_message>Passed Virtis with RF greater than 1.0</pass_fail_message>
      <description_virtis>Pass, no restrictions</description_virtis>
      <error_messages_virtis></error_messages_virtis>
      <impact>1.000</impact>
      <abcd_category>A</abcd_category>
      <r_or_s_Flag>S</r_or_s_Flag>
      <nbi_max_span_length>69.69</nbi_max_span_length>
      <inv_rf>2.397</inv_rf>
      <op_rf>4.002</op_rf>
      <impact>1.000</impact>
    </bridge>
  </results>
</MDOTrouting Output>
```

APPENDIX G – BridgeOV-Virtis API

```
<bridge>
  <controls>TRUE</controls>
  <vehicle_name>Test Vehicle</vehicle_name>
  <rating_level>-</rating_level>
  <bridge_id>82182023000S270</bridge_id>
  <route_id>00006</route_id>
  <pass_fail>FAILED</pass_fail>
  <process>S-Flag</process>
  <pass_fail_message>One axle is greater than 38 kip</pass_fail_message>
  <description_virtis>-</description_virtis>
  <error_messages_virtis>Failed S-Flag</error_messages_virtis>
  <impact>-</impact>
  <abcd_category>B</abcd_category>
  <r or s Flag>S</r or s Flag>
  <nbi_max_span_length>69.69</nbi_max_span_length>
  <inv_rf>-</inv_rf>
  <op_rf>-</op_rf>
  <impact>-</impact>
</bridge>
<bridge>
  <controls>TRUE</controls>
  <vehicle_name>Test Vehicle</vehicle_name>
  <rating_level>-</rating_level>
  <bridge_id>82182023000S270</bridge_id>
  <route_id>00006</route_id>
  <pass_fail>PASS</pass_fail>
  <process>BridgeOV</process>
  <pass_fail_message>Passed BridgeOV for Category A</pass_fail_message>
  <description_virtis>-</description_virtis>
  <error_messages_virtis>-</error_messages_virtis>
  <impact>-</impact>
  <abcd_category>F</abcd_category>
  <r or s Flag>S</r or s Flag>
  <nbi_max_span_length>50</nbi_max_span_length>
  <inv_rf>-</inv_rf>
  <op_rf>-</op_rf>
  <impact>-</impact>
</bridge>
<bridge>
  <controls>TRUE</controls>
  <vehicle_name>Test Vehicle</vehicle_name>
  <rating_level>-</rating_level>
  <bridge_id>82182023000S270</bridge_id>
  <route_id>00006</route_id>
  <pass_fail>FAILED</pass fail>
  <process>S-Flag</process>
  <pass_fail_message>One axle is greater than 38 kip</pass_fail_message>
  <description_virtis>-</description_virtis>
  <error_messages_virtis>Failed S-Flag</error_messages_virtis>
  <impact>-</impact>
  <abcd_category>G</abcd_category>
  <r or s Flag>S</r or s Flag>
  <nbi_max_span_length>85</nbi_max_span_length>
  <inv_rf>-</inv_rf>
  <op_rf>-</op_rf>
  <impact>-</impact>
</bridge>
<bridge>
  <controls>TRUE</controls>
  <vehicle_name>Test Vehicle</vehicle_name>
  <rating_level>-</rating_level>
  <bridge_id>junk bridge C</bridge_id>
  <route_id>00006</route_id>
  <pass fail>PASS</pass fail>
  <process>BridgeOV</process>
  <pass_fail_message>Passed BridgeOV for Category C</pass_fail_message>
  <description_virtis>-</description_virtis>
  <error messages virtis>-</error_messages_virtis>
  <impact>-</impact>
  <abcd category>C</abcd category>
  <r_or_s_Flag>R</r_or_s_Flag>
```

APPENDIX G – BridgeOV-Virtis API

```
<nbi_max_span_length>69.69</nbi_max_span_length>
<inv_rf>-</inv_rf>
<op_rf>-</op_rf>
<impact>-</impact>
</bridge>
<bridge>
  <controls>-</controls>
  <vehicle_name>
  </vehicle_name>
  <rating_level>-</rating_level>
  <bridge_id>junk bridge C</bridge_id>
  <route_id>00006</route_id>
  <pass_fail>ERROR</pass_fail>
  <process>BridgeOV</process>
  <pass_fail_message>Invalid Category: X
: Must be A,B,C,D,F,G, or H</pass_fail_message>
  <description_virtis>-</description_virtis>
  <error_messages_virtis>-</error_messages_virtis>
  <impact>-</impact>
  <abcd_category>X</abcd_category>
  <r_or_s_Flag>R</r_or_s_Flag>
  <nbi_max_span_length>69.69</nbi_max_span_length>
  <inv_rf>-</inv_rf>
  <op_rf>-</op_rf>
  <impact>-</impact>
</bridge>
<bridge>
  <controls>TRUE</controls>
  <vehicle_name>Test Vehicle</vehicle_name>
  <rating_level>-</rating_level>
  <bridge_id>MDOT-Failed</bridge_id>
  <route_id>00006</route_id>
  <pass_fail>PASS</pass_fail>
  <process>BridgeOV</process>
  <pass_fail_message>Passed BridgeOV for Category A</pass_fail_message>
  <description_virtis>-</description_virtis>
  <error_messages_virtis>-</error_messages_virtis>
  <impact>-</impact>
  <abcd_category>A</abcd_category>
  <r_or_s_Flag>R</r_or_s_Flag>
  <nbi_max_span_length>69.69</nbi_max_span_length>
  <inv_rf>-</inv_rf>
  <op_rf>-</op_rf>
  <impact>-</impact>
</bridge>
</results>
</MDOTrouting_Output>
```


APPENDIX G – BridgeOV-Virtis API

The XSL style sheet for this example is shown below:

```
<xsl:stylesheet version="1.0" xmlns:xsl="http://www.w3.org/1999/XSL/Transform"
xmlns:xs="http://www.w3.org/2001/XMLSchema"
<xsl:template match="/">
<HTML>

<HEAD>
  <TITLE>
    <xsl:for-each select="MDOTrouting_Output">
<xsl:value-of select="permit application number"/>:
    <xsl:value-of select="application timestamp"/>
    <xsl:value-of select="requested by"/>
    <xsl:value-of select="max_span_length_factor"/>
  </xsl:for-each> <!--routing_output-->
  </TITLE>
</HEAD>
<BODY>
  <H4>
    <xsl:for-each select="MDOTrouting_Output">
      <p> Permit Application Number: <xsl:value-of select="permit_application_number"/> </p>
      <p> Application Date: <xsl:value-of select="application_timestamp"/> </p>
      <p> Requested By: <xsl:value-of select="requested_by"/> </p>
      <p> <RIGHT>Process Date: <xsl:value-of select="process_timestamp"/> </RIGHT> </p>
      <p> <RIGHT>Maximum Span Length Factor: <xsl:value-of select="max_span_length_factor"/>
</RIGHT> </p>
    </xsl:for-each>
  </H4>
  <xsl:for-each select="MDOTrouting_Output">
    <xsl:for-each select="results">
      <CAPTION><LEFT><BR/><BR/><B>ROUTING RESULTS OUTPUT</B></LEFT></CAPTION>
      <TABLE BORDER="2">
        <THEAD>
          <TR>
            <TH WIDTH="180">Vehicle</TH>
            <TH WIDTH="180">Rating Level</TH>
            <TH WIDTH="180">Bridge ID</TH>
            <TH WIDTH="100">Route ID</TH>
            <TH WIDTH="100">PASS-FAIL</TH>
            <TH WIDTH="100">Process</TH>
            <TH WIDTH="100">PASS-FAIL Message</TH>
            <TH WIDTH="100">Description</TH>
            <TH WIDTH="100">Additional Message</TH>
            <TH WIDTH="100">Conditions</TH>
            <TH WIDTH="80">Impact</TH>
            <TH WIDTH="80">A, B, C, D Category</TH>
            <TH WIDTH="200">R or S Flag</TH>
            <TH WIDTH="100">NBI Max Span Length</TH>
            <TH WIDTH="100">Inventory RF</TH>
            <TH WIDTH="100">Operating RF</TH>
          </TR>
        </THEAD>
        <TBODY>
          <xsl:for-each select="bridge">
            <TR>
              <TD ALIGN="center" VALIGN="top"><xsl:value-of select="vehicle_name"/></TD>
              <TD ALIGN="center" VALIGN="top"><xsl:value-of select="rating_level"/></TD>
              <TD ALIGN="center" VALIGN="top"><xsl:value-of select="bridge id"/></TD>
              <TD ALIGN="center" VALIGN="top"><xsl:value-of select="route_id"/></TD>
              <xsl:for-each select="pass_fail">
                <xsl:choose>
                  <xsl:when test="text() = 'PASS'">
                    <TD ALIGN="center" VALIGN="top" style="color:blue">
                      <xsl:value-of select="text()"/></TD>
                  </xsl:when>
                  <xsl:when test="text() = 'FAILED'">
                    <TD ALIGN="center" VALIGN="top" style="color:red">
                      <xsl:value-of select="text()"/></TD>
                  </xsl:when>
                  <xsl:when test="text() = 'ERROR'">

```

APPENDIX G – BridgeOV-Virtis API

```
<TD ALIGN="center" VALIGN="top" style="color:red">
  <xsl:value-of select="text()" /></TD>
</xsl:when>
<xsl:otherwise>
  <TD ALIGN="center" VALIGN="top" style="color:green">
    <xsl:value-of select="text()" /></TD>
  </xsl:otherwise>
</xsl:choose>
</xsl:for-each>
<TD ALIGN="center" VALIGN="top"><xsl:value-of select="process" /></TD>
<TD ALIGN="center" VALIGN="top"><xsl:value-of select="pass_fail_message" /></TD>
<TD ALIGN="center" VALIGN="top"><xsl:value-of select="description_virtis" /></TD>
<TD ALIGN="center" VALIGN="top"><xsl:value-of select="error_messages_virtis" /></TD>
<TD ALIGN="center" VALIGN="top">
  <TABLE>
    <xsl:for-each select="conditional_pass/condition">
      <TR>
        <TD ALIGN="left">
          <xsl:if test="text() = 10">
            <xsl:value-of select="text()" /> - Truck speed restriction to 5 mph</xsl:if>
          <xsl:if test="text() = 11">
            <xsl:value-of select="text()" /> - Bridge restricted to all other vehicles</xsl:if>
          </TD>
        </TR>
      </xsl:for-each> <!--conditional_pass/condition-->
    </TABLE>
  </TD>
  <TD ALIGN="center" VALIGN="top"><xsl:value-of select="impact" /></TD>
  <TD ALIGN="center" VALIGN="top"><xsl:value-of select="abcd_category" /></TD>
  <TD ALIGN="center" VALIGN="top"><xsl:value-of select="r_or_s_Flag" /></TD>
  <TD ALIGN="center" VALIGN="top"><xsl:value-of select="nbi_max_span_length" /></TD>
  <TD ALIGN="center" VALIGN="top"><xsl:value-of select="inv_rf" /></TD>
  <TD ALIGN="center" VALIGN="top"><xsl:value-of select="op_rf" /></TD>
</TR>
</xsl:for-each>
</TBODY>
</TABLE>
</xsl:for-each> <!--results-->
</xsl:for-each> <!--routing_output-->
</BODY>
</HTML>
</xsl:template>
</xsl:stylesheet>
```

APPENDIX G – BridgeOV-Virtis API

The browser view of the XML file with the XSL style sheet is shown below:

Permit Application Number: 6857asdf

Application Date: 10/14/2012 5:34:59 PM

Requested By: John Doe

Process Date:

Maximum Span Length Factor: 1.0

ROUTING RESULTS OUTPUT

Vehicle	Rating Level	Bridge ID	Route ID	PASS-FAIL	Process	PASS-FAIL Message	Description	Additional Message	Conditions	Impact	A,B,C,D Category	R or S Flag	NBI Max Span Length	Inventory RF	Operating RF
Test Vehicle	Operating	82182023000S270	00006	PASS	Virtis	Passed Virtis with RF greater than 1.0	Pass, no restrictions	-		1.000	A	S	69.69	2.397	4.002
Test Vehicle	-	82182023000S270	00006	FAILED	S-Flag	One axle is greater than 38 kip	-	Failed S-Flag		-	B	S	69.69	-	-
Test Vehicle	-	82182023000S270	00006	PASS	BridgeOV	Passed BridgeOV for Category A	-	-		-	F	S	50	-	-
Test Vehicle	-	82182023000S270	00006	FAILED	S-Flag	One axle is greater than 38 kip	-	Failed S-Flag		-	G	S	85	-	-
Test Vehicle	-	junk bridge C	00006	PASS	BridgeOV	Passed BridgeOV for Category C	-	-		-	C	R	69.69	-	-
	-	junk bridge C	00006	ERROR	BridgeOV	Invalid Category: X: Must be A,B,C,D,F,G, or H	-	-		-	X	R	69.69	-	-
Test Vehicle	-	MDOT-Failed	00006	PASS	BridgeOV	Passed BridgeOV for Category A	-	-		-	A	R	69.69	-	-

Output File Format

The following table provides a description for the XML output file produced by BridgeOV-Virtis.

XML Tag	Description
<MDOTrouting_Output>	Indicates the beginning of the routing information
<file_version>	Indicates the version of the routing request file. Should be 1.0.
<permit_application_number>	Permit application number for tracking purposes
<requested_by>	Name of person submitting the routing request file
<application_timestamp>	Time that the routing request file was created
<structural_analysis_type>	This can be either 'Standard' or 'Nonstandard'. 'Nonstandard' is for non-standard gage analysis in Virtis.
<max_span_length_factor>	This value is an echo of the value provided in the input
<results>	Indicates start of list of results for each bridge.
<bridge>	Indicates start of data for a bridge on the route
<controls>	Set to TRUE if this version of the bridge run controls. Note: some bridges may have multiple results or <bridge> nodes since Virtis will analyze for different scenarios.
<vehicle_name>	Vehicle name as provided in the input.
<rating_level>	Rating level to govern as provided in the user input. Can be either 'Inventory' or 'Operating'
<bridge_id>	Bridge ID as provided in the user input.
<route_id>	Route ID as provided in the user input
<pass_fail>	Field indicating one of the following: 'PASS' – vehicle passes this bridge 'PASS-(Conditional)' – Passes Virtis but with some conditions that are displayed in the <conditional_pass>-<condition> tags. 'FAILED' – bridge did not pass 'ERROR' – some type of error has occurred. See error message column for details.

APPENDIX G – BridgeOV-Virtis API

XML Tag	Description
<process>	Lists the process used to analyze the bridge. The choices are: 'Virtis' – results are from Virtis 'BridgeOV' –results are from BridgeOV 'S-Flag' – bridge failed using the 38 kip axle check.
<pass_fail_message>	A description field providing more information on the PASS/FAIL message.
<error_messages_virtis>	Any error messages produced by Virtis are provided here.
<conditional_pass> <condition>	Multiple 'condition' tags may be listed. The options for conditional passing may be: 10 - Truck speed restriction to 5 mph 11 - Bridge restricted to all other vehicles
<impact>	The controlling impact factor
<abcd_category>	ABCD class as provided in the input.
<r_or_s_Flag>	R or S flag as provided in the input
<nbi_max_span_length>	The maximum structure span length as provided in the input
<inv_rf>	Inventory rating factor as provided by Virtis. If this bridge was not in the Virtis database or was not able to be analyzed in Virits, the value will be a '-'.
<op_rf>	Operating rating factor as provided by Virtis. If this bridge was not in the Virtis database or was not able to be analyzed in Virits, the value will be a '-'.

Auxiliary Files

In addition to the API input and output files, the BridgeOV-Virtis process creates several auxiliary files. These files are used interface. For all files the 'Root' represents the main part of the initial input file. For example if the input routing file is named:

SmallTestSample.mdr

The prefix or 'SmallTestSample' is considered the 'Root'. Using this definition, the auxiliary files produced by the process are defined in the following table.

File name	Description
'Root'.mdr	Initial input file. Created by the user or process that call BridgeOV-Virtis
'Root'Output_SUM.XML	Main output summary file in XML. This file would be used as the final output file for MiTRIP
'Root'Output_SUM.XSL	The accompanying style sheet for the formatting the 'Root'Output_SUM.XML file. This style sheet can be used to display the XML output file or the file can be parsed directly and the results presented in another form within MiTRIP.
'Root'-XXX-'BridgeID'.XMI	Individual Bridge input file for running Virtis. Each bridge ID in the routing list is run individually through Virtis if applicable. Each 'BridgeID' has its own input file created that is fed into Virtis. The 'XXX' in the file name represents a sequential number for the BridgeID. Note: This file will only be generated if an attempt is made to run Virtis. E.g. if this is a class B or C bridge with an 'S' flag and one of the vehicle axles is over 38 kips, there is no need to run Virtis, so the input file is not generated. See the system flow chart if Figure 79 and Figure 80 for more details.
'Root'Output-XXX-'BridgeID'.XML	Individual Bridge input file for running Virtis. Each bridge ID in the routing list is run individually through Virtis if applicable. Each 'BridgeID' has its own output XML file created by Virtis and an accompanying XSL stylesheet for viewing the output file. Also available is an XMS file. This is a status file with some information on when the bridge was
'Root'Output-XXX-'BridgeID'.XSL	
'Root'Output-XXX-'BridgeID'.XMS	

	<p>run (including a start and end time).</p> <p>The 'XXX' in the file name represents a sequential number for the BridgeID.</p> <p>Note: This file will only be generated if an attempt is made to run Virtis. E.g. if this is a class B or C bridge with an 'S' flag and one of the vehicle axles is over 38 kips, there is no need to run Virtis, so the input file is not generated. See the system flow chart if Figure 79 and Figure 80 for more details.</p>
<p>'Root'-STD-'VehicleID'.txt 'Root'-STD-'VehicleID'.out</p>	<p>BridgeOV input (.txt) and output (.out) files for the standard 8' gage vehicle. These files contain the input into BridgeOV and the output produced by BridgeOV. Since multiple vehicles may be run for the same bridge list, the 'VehicleID' is the vehicle description provided in the input XML file.</p> <p>For a description on the BridgeOV input and output see Sections 10.3.3 and 10.3.4 of this manual.</p>
<p>'Root'-ACT-'VehicleID'.txt 'Root'-ACT-'VehicleID'.out</p>	<p>BridgeOV input (.txt) and output (.out) files for the actual gages input for the vehicle. These files contain the input into BridgeOV and the output produced by BridgeOV. Since multiple vehicles may be run for the same bridge list, the 'VehicleID' is the vehicle description provided in the input XML file.</p> <p>For a description on the BridgeOV input and output see sections 10.3.3 and 10.3.4 of this manual.</p>

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Appendix H – Weigh-in-Motion – (WIM) file format

The following format is for WIM files for MDOT. These WIM files can be read in as an alternate file format in the Permit Vehicle Analyzer (PVA) program.

Each vehicle record will be 112 characters long.

Description	Value/comments	Columns
Record type	Always 'W'	0
State Code	Always '26' for Michigan	1-2
County Code	2 digit	3-4
Site ID	4 digit	5-8
Direction code	1 digit – 1 1 north, 2 NE, 3 East, 4 SE, 5 South, 6 SW, 7 West, 8 NW.	9
Lane number	1 digit right lane for any direction is always 1 then next lane 2 etc...	10
Year	2 digit	11-12
Month	2 digit	13-14
Day	2 digit	15-16
Hour	2 digit 01-24 (e.g. midnit to 1 AM – 00)	17-18
Vehicle class	2 digit – Standard FHWA 13 class scheme	19-20
Speed	3 digit	21-23
Gross weight	4 digit	24-27
Number of axles	2 digit	28-29
Axle wgts spacings	75 digit – Ax 1 wgt, ax(1-2) spcg, Ax2 wght, Ax(2-3) spcg, Ax3 wgt Ax (n-1) wgt, Ax (n-1)-n spcg, Ax n wgt	30-104
Minute	2 digit	105-106
Second	2 digit	107-108
Millisecond	3 digit	109-111

The 4 digit gross weight, the 3 digit weight and the 3 digit spacings are set up with a single place decimal implied. So a weight of 104 would equate to 10.4 kips or 10,400 lbs. A spacing of 434 would be 43.4 ft. A 4 digit gross weight of 1057 would equate to 105.7 kips or 105,700 lbs.

APPENDIX H – Weigh-in-Motion (WIM) file format

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