Parameter-Driven Creation of 2D Traditional Style Drawings, 3D Models, and Analytical Models: A Quantum Leap in Efficiency

Doug Dunrud, WSP

IBC 24-XX

Douglas J. Dunrud, PE

VICE PRESIDENT/TECHNICAL PRINCIPAL
BIM/DIGITAL DELIVERY SUBJECT MATTER EXPERT

YEARS OF EXPERIENCE

36

YEARS with WSP

6 years

EDUCATION

B.S. Civil Engineering/

CAREER SUMMARY

Mr. Dunrud has 36 years of experience as a bridge engineer in the highway transportation sector. He has a demonstrated record of managing projects scope (quality), schedule and budget that meets or exceeds the stakeholders expectations. He is a pioneer in the development of Building Information Modeling (BIM) for bridges and structures and Virtual Design and Construction (VDC) which promises to improve quality, accelerate project schedules and increase value to clients on transportation infrastructure projects.

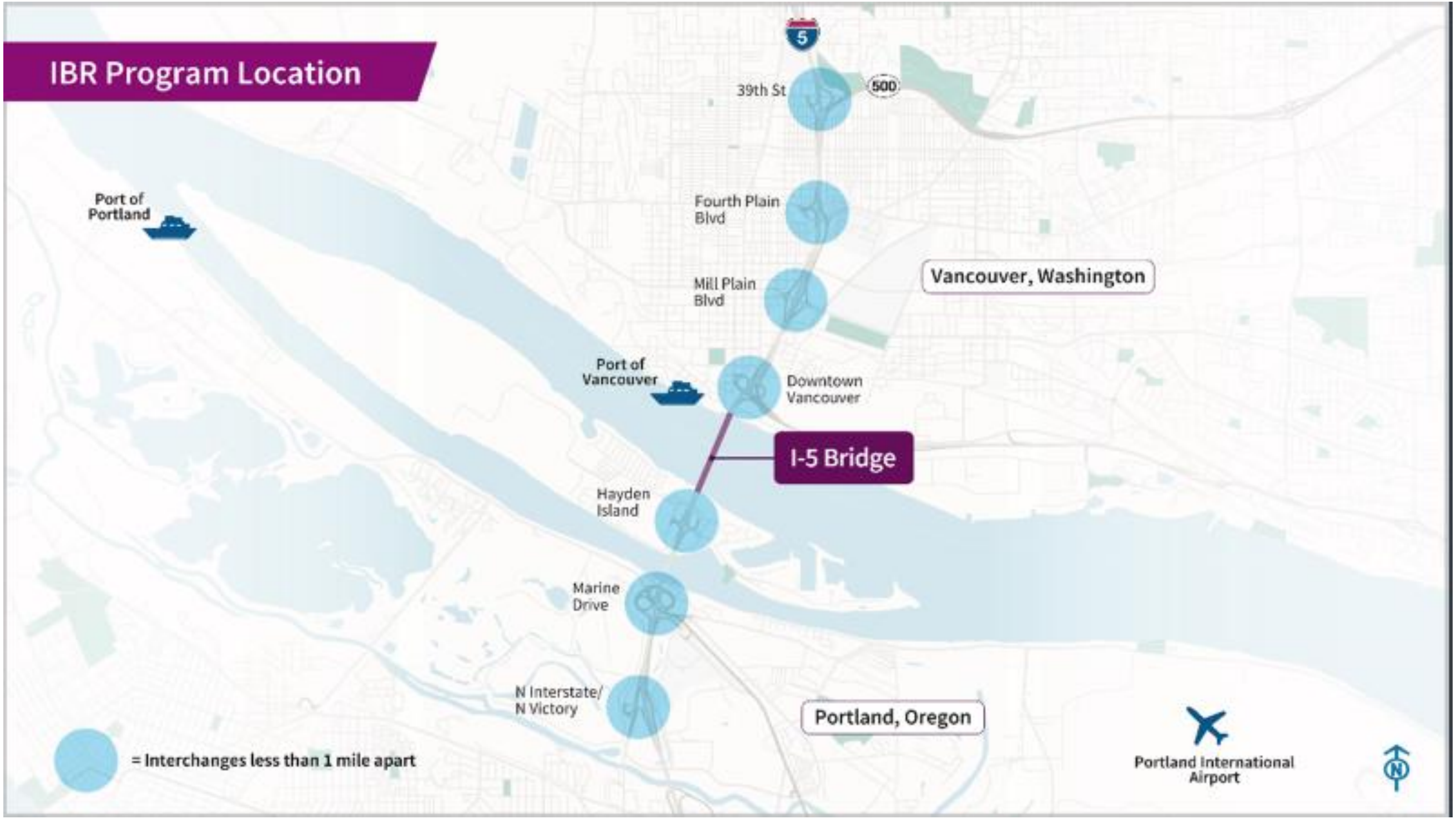
PROFESSIONAL EXPERIENCE

Vice President, Technical Principle, WSP-USA: As part of the National Bridge & Structures Practice, Mr. Dunrud is a national resource to WSP's U.S Transportation and Infrastructure Sector. He provides hands-on expertise with multiple software packages and has demonstrated an ability to help teams transition from CAD to BIM. He is leading the effort to deliver Digital Twins and utilize model-centric workflows for producing plans and quantities. Since August of 2020, Doug has been leading the BIM effort for the Structures Team on the $6 billion Interstate Bridge Replacement (IBR) project including producing all the project deliverables from the model. He is leading WSP's effort to utilize OpenBrIM, which combines structural analysis and Level of Development (LOD) 400 detailing. Doug is also leading a team on the K-96 project in Kansas to model the 5 bridges using BIM.
(February 2018 to Feb 2024)

Bridge Modeling Basic Principles

1. **Accurate** - the number one reason to model bridges is to build virtually what we intend to build physically so that delays and cost over-runs can be avoided during construction.
2. **Fast -** Unless we can produce construction documentation quickly and efficiently, traditional CAD will continue to be the standard practice.
3. **Dynamic -** Change management is facilitated by utilizing construction documentation that are “extracts” from parametric 3D models.

Paradigm Shift: The Transportation Infrastructure industry needs to transition from putting information on electronic pieces of paper to putting information in 3D models and extracting construction documents from the models.


IBR Program Location
5
500
39th St
Fourth Plain Blvd
Mill Plain Blvd
Port of Portland
Port of Vancouver
Downtown Vancouver
Vancouver, Washington
I-5 Bridge
Hayden Island
Marine Drive
N Interstate/ N Victory
Portland, Oregon
= Interchanges less than 1 mile apart
Portland International Airport
N

I. Workflow Comparison

Workflow Comparisons for IBR land bridges

#	Delivery Workflow	Grasshopper/ Rhino			Bentley - OBM/ProConcrete			Autodesk - Infraworks/Dynamo/Revit			OpenBrIM -		
1	Import .alg and .dtm from Open Roads	1	2	1	1	1	1	2	2	1	2	1	1
		The Grasshopper script has been develped to import ORD and changing geomtery references is simple.			Importing ORD is the basic Bentley workflow in OBM.			A custom script will need to be developed in Dynamo unless the Grashopper script is used.			A custom script will need to be developed		
2	Model bridge geometry (LOD 300)	1	2	1	1	2	2	1	3	2	1	1	1
		The Grasshopper script has been develped and revisions to Grasshopper requires medium skill level.			OBM is simple to use but modifying templates requires medium skill. Some unique features may require Generative Components.			A custom script will need to be developed in Dynamo unless the Grashopper script is used.			OpenBrIM models can be created from templates.		
3	Full development of bridge model (LOD 400)	1	3	1	2	3	2	1	3	2	1	1	1
		The Grasshopper script has been develped but modeling rebar in Grasshopper requires a high skill level.			ProConcrete requires a medium skill level to model rebar. Demonstration is required to prove that there are no limitation in getting model to LOD 400.			Revit requires a medium skill level to model rebar. Demonstration is required to prove that there are no limitation in getting model to LOD 400.			Demonstration is required to prove that there are no limitation in getting model to LOD 400.		
4	Producing deliverables (ie plans and quantities)	2	3	1	1	2	2	1	2	2	2	1	2
		Linework for drawings and quantities are produced in Grasshopper. Addition effort in Microstation to produce drawings.			Drawings and quantities produced in ProConcrete.			Drawings and quantities produced in Revit.			Linework is created using OpenBrIM and referenced into Microstation to produce drawings.		
5	Interoperability with analysis programs	1	3	1	1	1	2	1	1	1	1	1	1
		Grasshopper script to link model to LARSA has been developed. Additional effort is necessary to link to other analytical software.			Common data environment is linked to LEAP and RM.			Revit linked to various analytical software.			FEA is part of OpenBrIM		
6	Clash detection/ 4D Construction Scheduling.	2	3	2	1	1	1	1	1	1	1	1	1
		Grasshopper scripting needed for clash detection. Link to Sychro is managable.			Sychro can be used for clash detection and 4D scheduling with basic skill level.			Navisworks can be used for clash detection and 4D scheduling with basic skill level.			Export model to Navisworks or Synchro		
7	export to ifc for fabrication	1	2	1	1	1	1	1	1	1	1	1	2
		Export to ifc from Grasshopper has to be verified.			Export to ifc is part of the basic OBM workflow.			Export to ifc is part of the Revit workflow.			Export to ifc from OpenBrIM has to be verified.		
8	export to SQL	1	2	1	1	1	1	2	2	2	1	1	1
		Export to iTwin from Grasshopper has to be verified.			Export to iTwin is part of the basic OBM workflow.			Export to iTwin from Revit will need to be developed. This will need to be developed for the buildings.			Export to SQL from OpenBrIM has to be verified.		
	Score =	39			33			37			28		

Level of Effort for production users	Level of Effort for automation developers	Limitations
1. Easy	1. Easy	1. No Limitation
2. Medium	2. Medium	2. Difficult workarounds
3. Difficult	3. Difficult	3. Some impossibilities *

* An impossibily may eliminate a workflow from contention.

Delivery Workflow

1. Import .alg and .dtm from OpenRoads
2. Model bridge geometry (LOD 200)
3. Producing deliverables (ie plans and quantities)
4. Interoperability with analysis programs
5. Clash detection/4D Construction Scheduling
6. Full development of bridge model (LOD 400)
7. Export to ifc for fabrication
8. Create a Digital Twin for Asset Management

Software Platforms

Rhinoceros
Grasshopper/
Tekla

Bentley - OpenBridge/
ProConcrete

Autodesk - Infraworks/
Dynamo/
Revit

OpenBrIM

Grading System

Level of Effort for Production Users	Level of Effort for Automation Developers	Limitations
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* An Impossibility may Eliminate a Workflow from Contention.

Final Scores

	Rhinoceros Grasshopper/ Tekla	Bentley - OpenBridge/ ProConcrete	Autodesk - Infraworks/ Dynamo/ Revit	OpenBrIM
Score =	39	33	37	28

II. Conceptual Design - Visualizations LOD 200 Models

1. Square feet of deck from model was used for Cost Estimates.
2. OBM models exported as kmz files to Google Earth for Cost Estimating Team.
3. Bridge models are coordinated with other disciplines (Roadway, Transit, Bridge Architect, Drainage, etc)
4. Visualizations utilize bridge models and serve as Quanlity Control
5. Models used for Environmental Documentation including Ship Simulations

Visualizations used Bridge Models

Visualizations for Quality Control

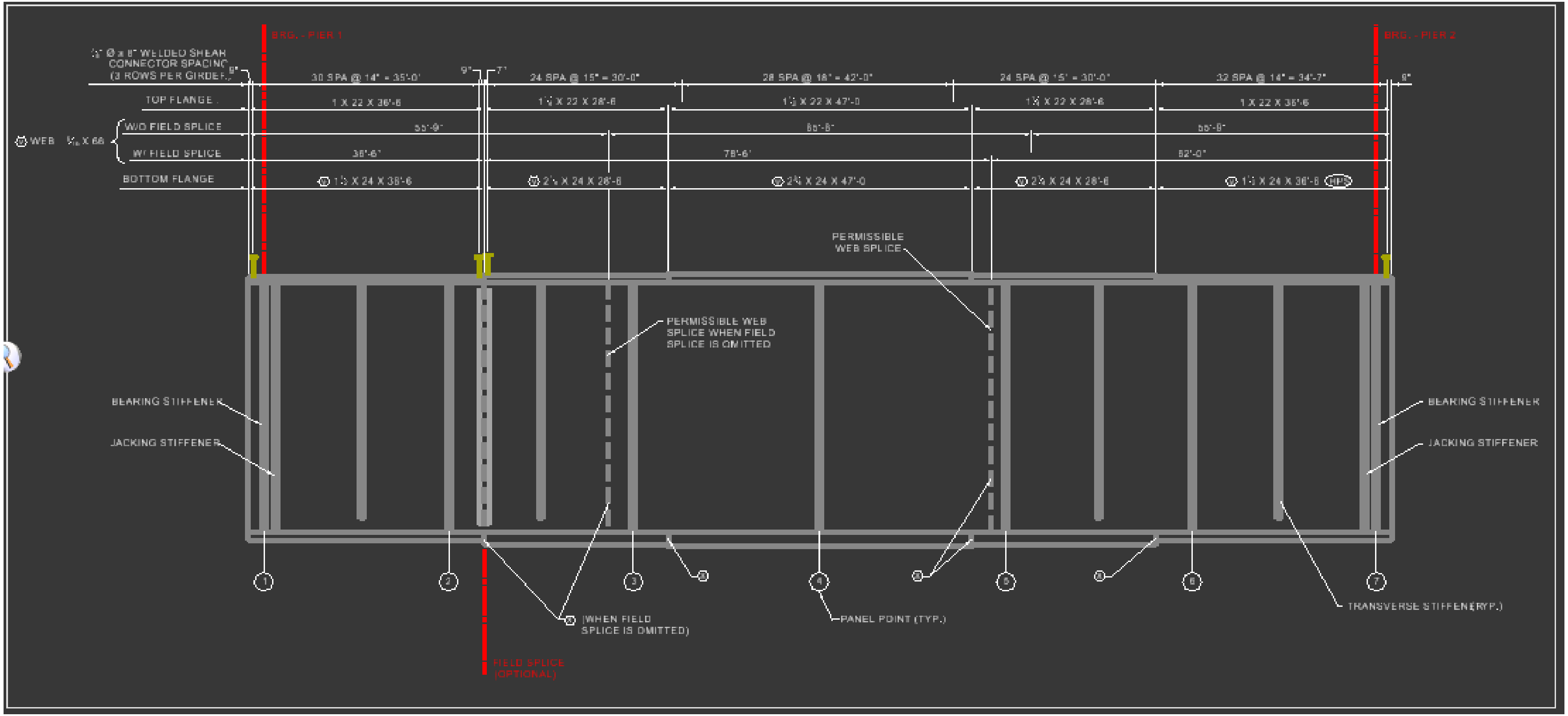
III. Preliminary Design - 30% Drawings

Parameter-Driven Creation of 2D Traditional Style Drawings

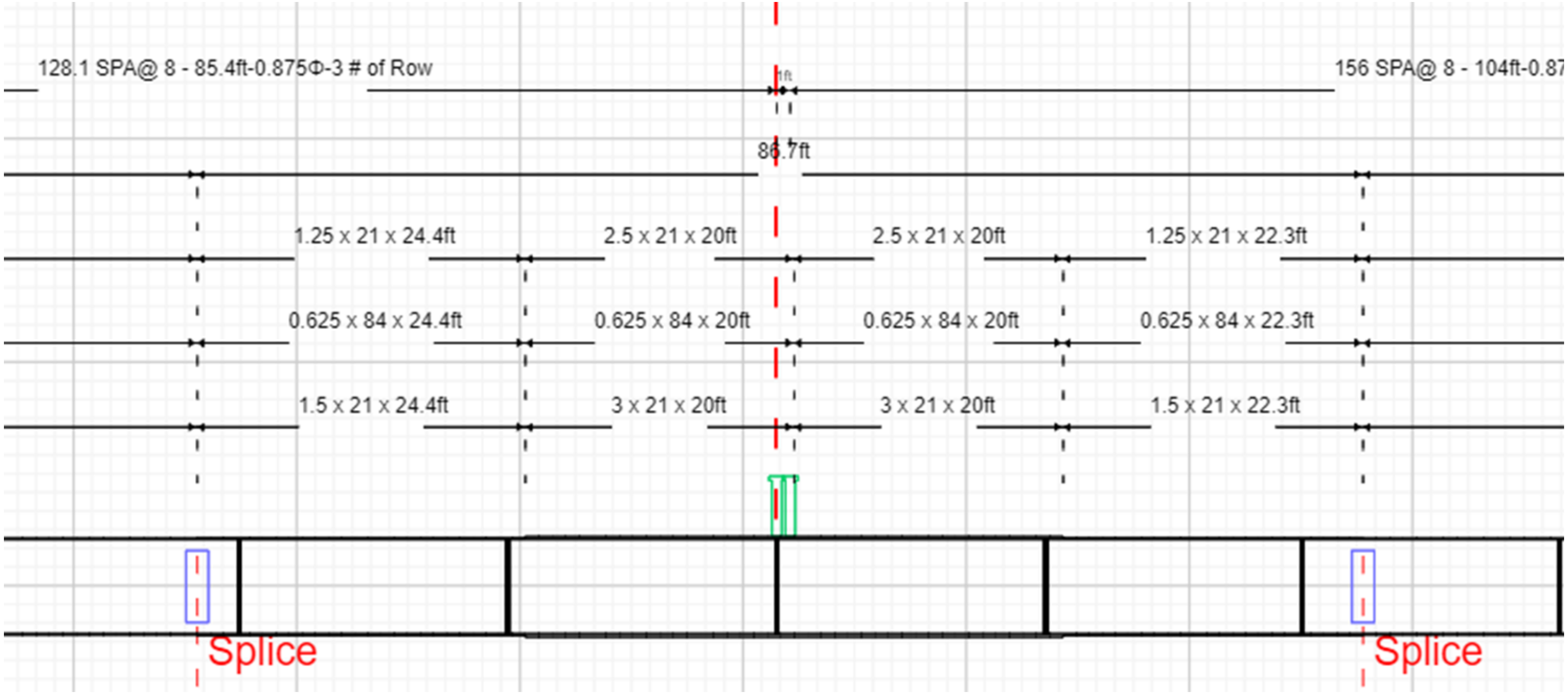
1. Automated 2D Drawings are significantly different than 2D “Ports” into the model.
2. Automated 2D Drawings can produce drawings that are indistinguishable from CAD Drawings.

*OpenBrIM Drawings are exported to ProjectWise Directly

1. Automated 2D Drawings are significantly different than 2D "Ports" into the model.



1. Automated 2D Drawings are significantly different than 2D "Ports" into the model.

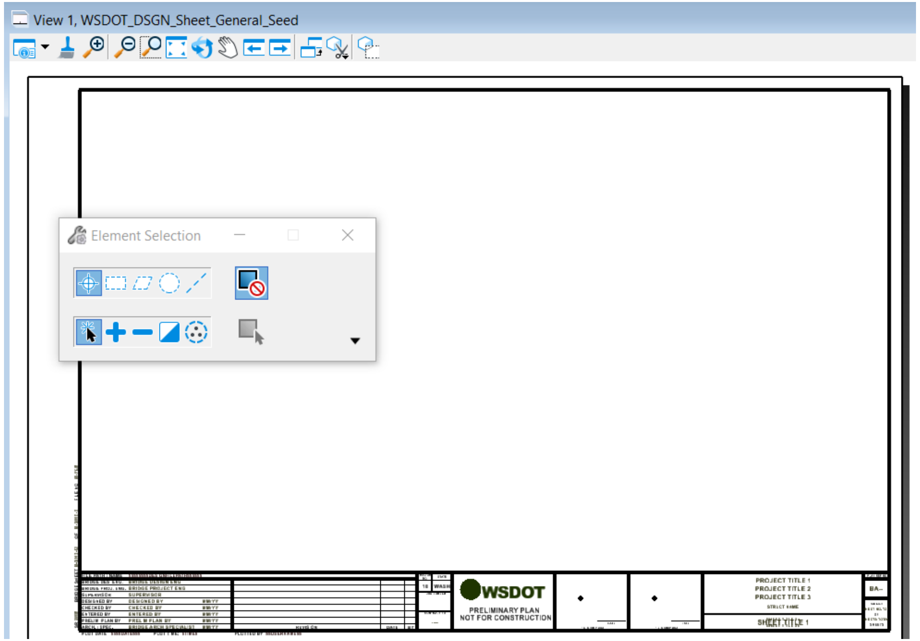


2. Automated 2D Drawings can produce drawings that are indistinguishable from CAD Drawings

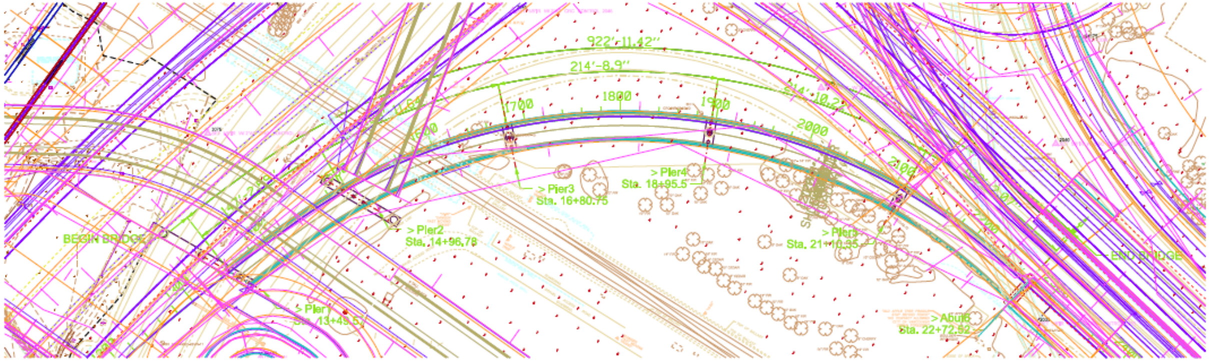
WSDOT Bridge Seed Files:

I. 2D_Bridge_Drawing_Seed
   - WSDOT Level
   - Annotation Styles
   - Fonts

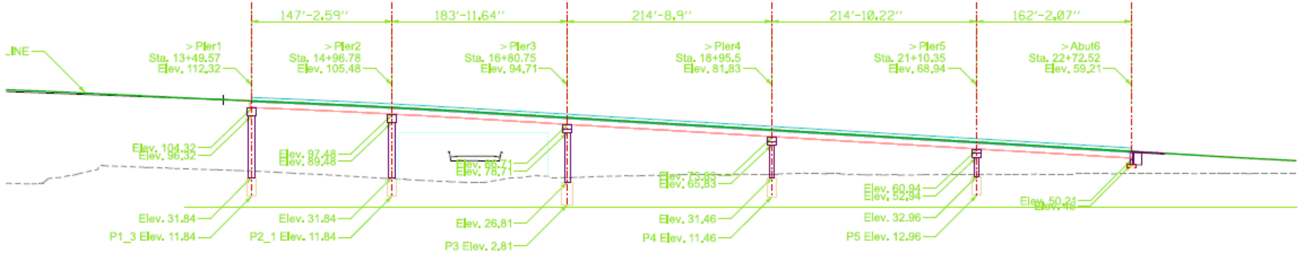
II. 2D_Bridge_Sheet_Seed
   - Border
   - Title Block “Tags”



OpenBrIM created using 2D_Bridge_Drawing_Seed and then referenced to 2D_Bridge_Sheet_Seed



PLAN



ELEVATION

FILE PATH / NAME	c:\bms\wsp-us-pw-09\dms69190\IBR040-IBR-WA-BR-14C5-XXX-B-SHT-0000001.dgn		
BRIDGE DES. ENG.	BRIDGE DESIGN ENG		
BRIDGE PROJ. ENG.	BRIDGE PROJECT ENG		
SUPERVISOR	SUPERVISOR		
DESIGNED BY	DESIGNED BY	MM/YY	
CHECKED BY	CHECKED BY	MM/YY	
ENTERED BY	ENTERED BY	MM/YY	
PRELIM. PLAN BY	PRELIM PLAN BY	MM/YY	
ARCH. / SPEC.	BRIDGE ARCH SPECIALIST	MM/YY	REVISION / DATE / BY

PLOT DATE: 5/16/2024 PLOT TIME: 9:50:24 AM PLOTTED BY: USDD667895

REGION NO. 10 STATE WASH

WSDOT

PRELIMINARY PLAN
NOT FOR CONSTRUCTION

PROJECT TITLE 1
PROJECT TITLE 2
PROJECT TITLE 3
STRUCT NAME
SHEET TITLE 1

BA—

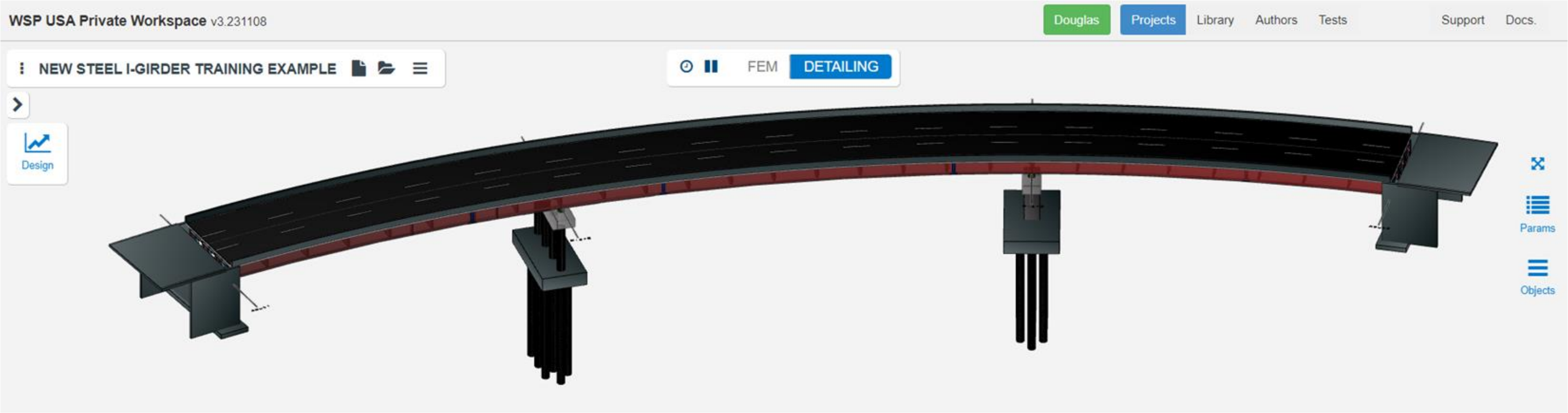
Drawing Production Grading

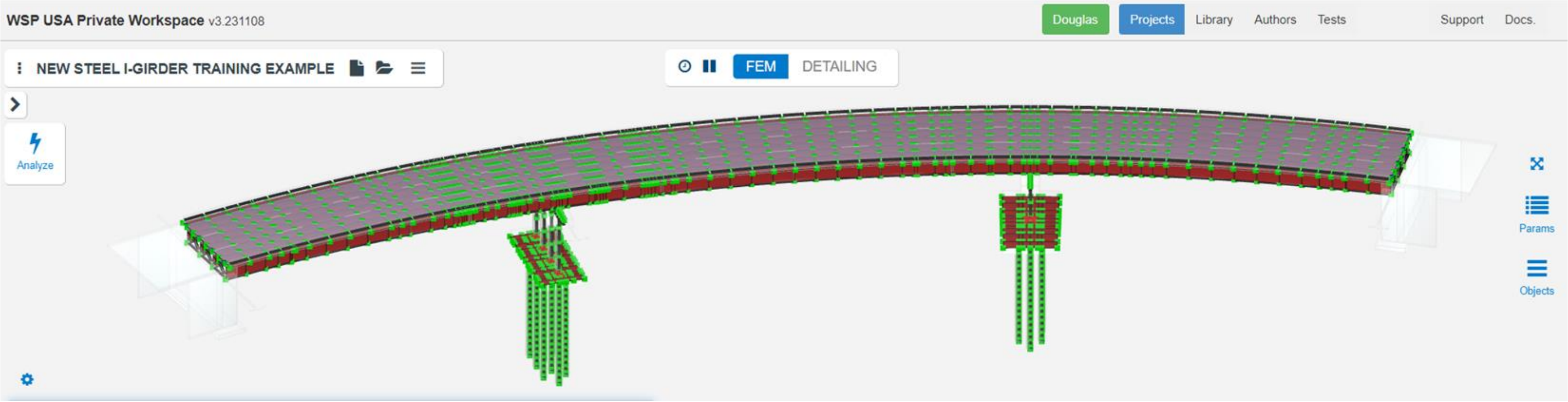
A	1.	**Accurate** - the number one reason to model bridges is to build virtually what we intend to build physically so that delays and cost over-runs can be avoided during construction.
A-	2.	**Fast -** Unless we can produce construction documentation quickly and efficiently, traditional CAD will continue to be the standard practice.
A+	3.	**Dynamic -** Change management is facilitated by utilizing construction documentation that are “extracts” from parametric 3D models.

IV. **Detailed Design - Design Calculations**

Analytical Models

1. Moving Loads - 3D Influence Surface-Based Analysis
2. Seismic Analysis
3. Load Rating Analysis


WSP USA Private Workspace v3.231108
Douglas
Projects
Library
Authors
Tests
Support
Docs.
NEW STEEL I-GIRDER TRAINING EXAMPLE
FEM
DETAILING
Design
Params
Objects


WSP USA Private Workspace v3.231108
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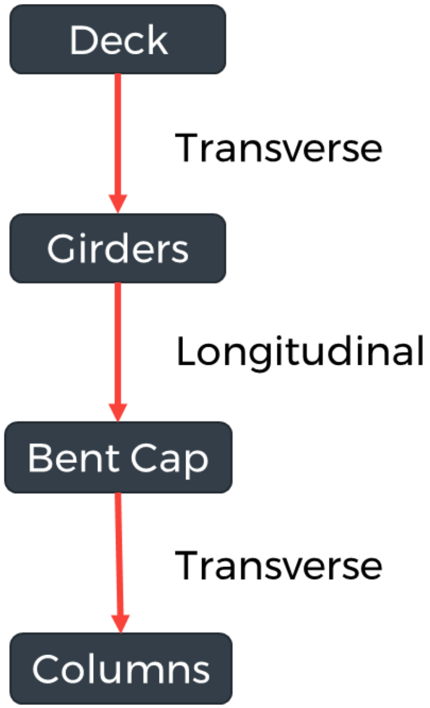
Objects

1. Moving Loads - 3D Influence Surface-Based Analysis



3.1.1 Load Path

The Engineer must provide a clear load path. The following illustrates the pathway of truck loading into the various elements of a box girder bridge.

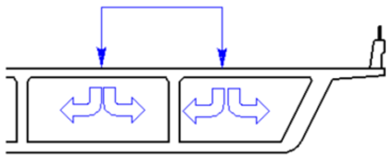


Figure 3.1-1 Truck Load Path from Deck Slab to Girders

The weight of the truck is distributed to each axle of the truck. One half of the axle load then goes to each wheel or wheel tandem. This load will be carried by the deck slab which spans between girders, see Figure 3.1-1.

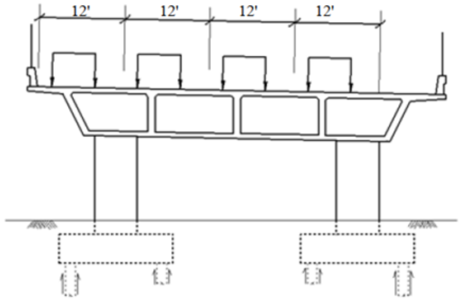


Figure 3.1-3 Truck Load on Bent Cap

Once the load has been transferred to the girders, the direction of the load path changes from transverse to longitudinal. The girders carry the load by spanning between bents and abutments (Figure 3.1-2).

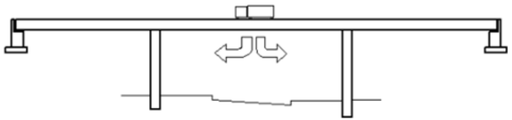
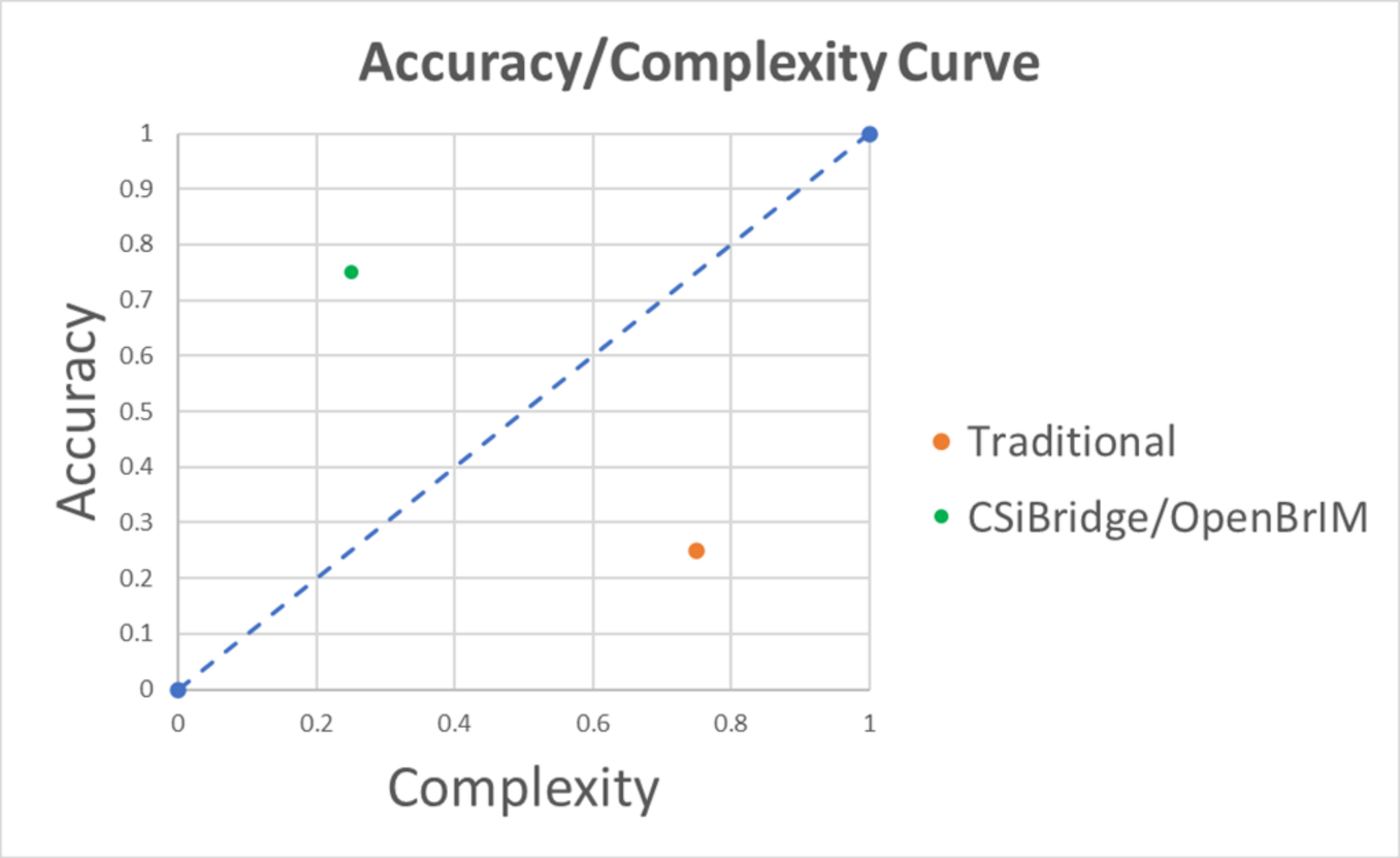
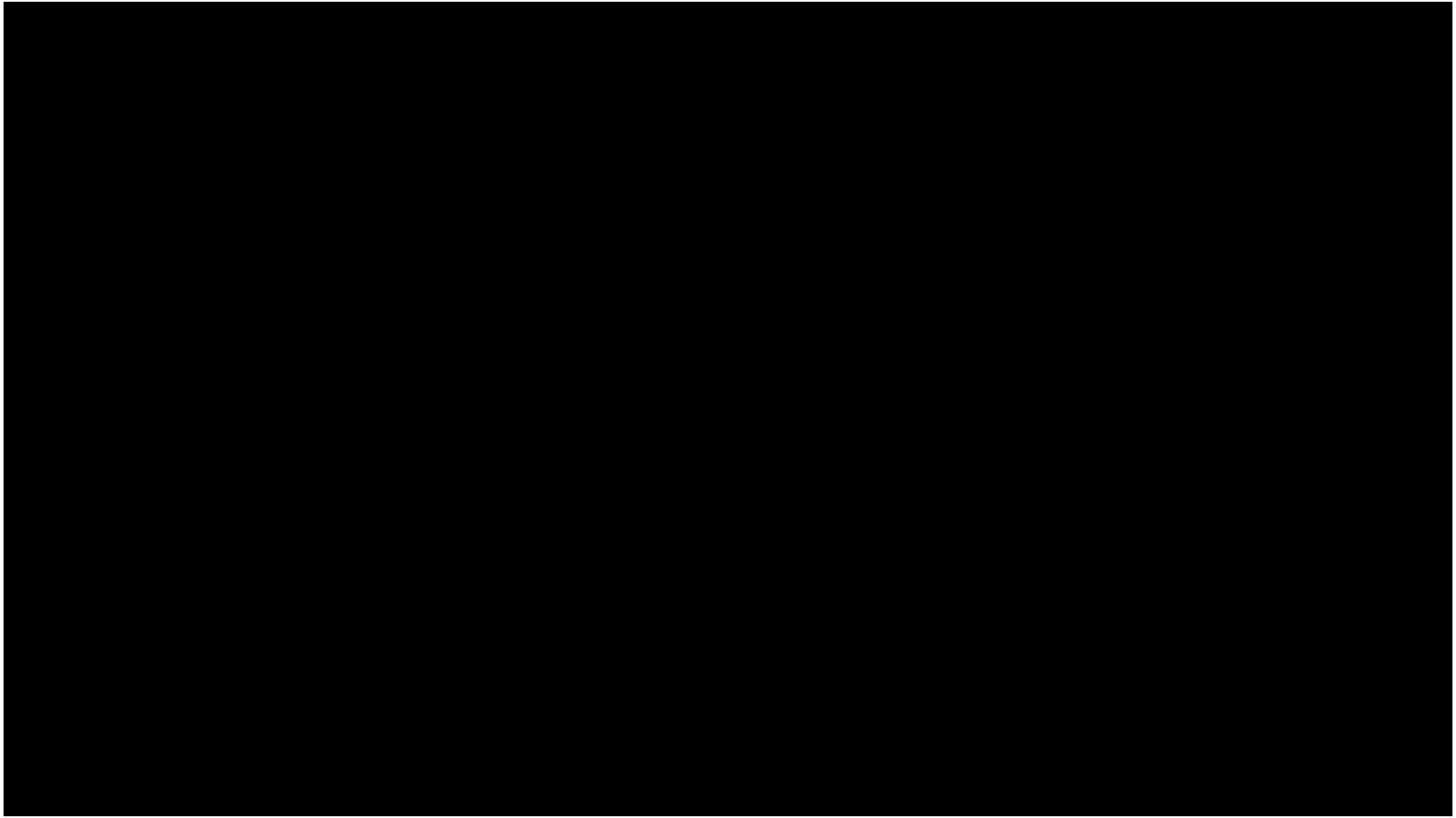


Figure 3.1-2 Truck Load Path from Girders to Bents

1. Moving Loads - 3D Influence Surface-Based Analysis



1. Moving Loads - 3D Influence Surface-Based Analysis



2. Seismic Analysis

Seismic Displacements (D) – From Modal Analysis

Displacement Capacity (C) – From Pushover Analysis

$D/C \geq 1.0$

2. Seismic Analysis - Demand

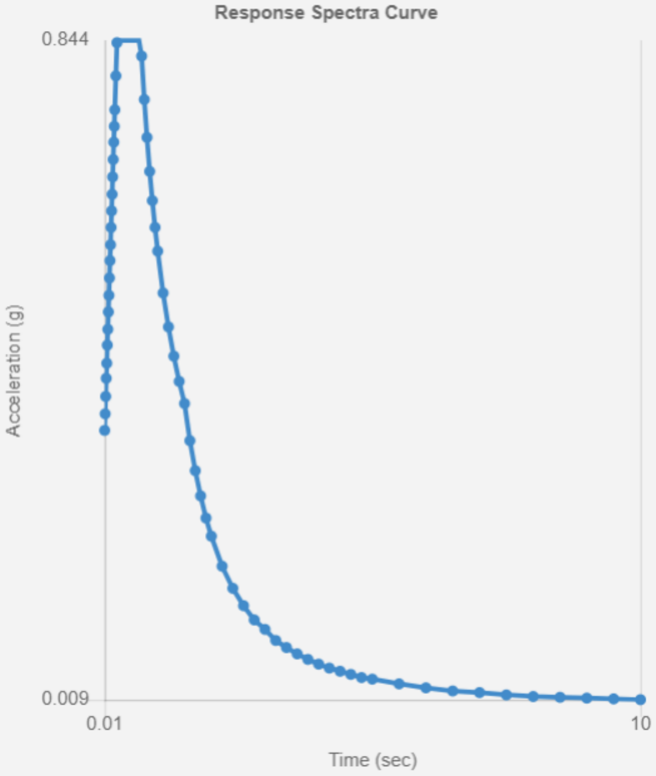
Response Spectrum Curve

Curve Name	CRC_975-yr

X Axis: Period

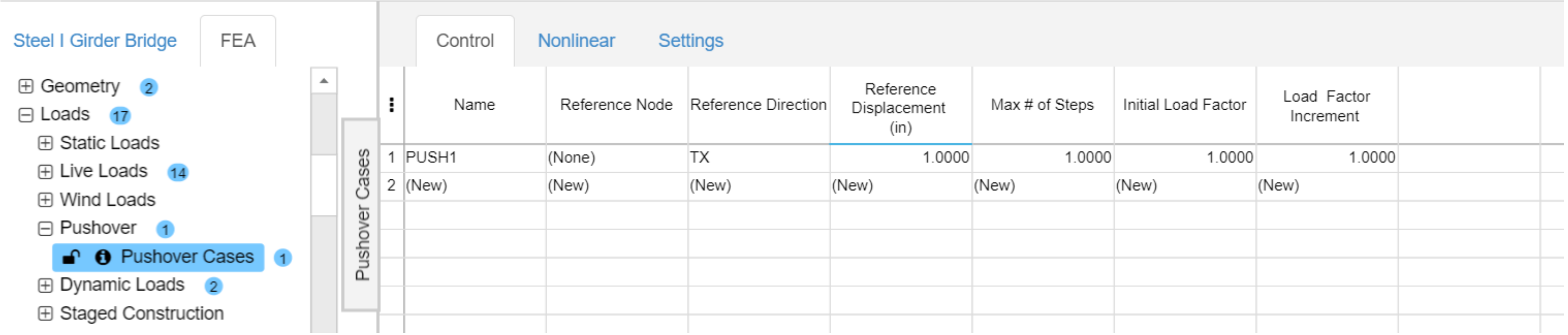
Y Axis: Acceleratio

	Period (sec)	Acceleration (g)
1	0.0100	0.3500
2	0.0200	0.3710
3	0.0300	0.3930
4	0.0400	0.4160
5	0.0500	0.4350
6	0.0600	0.4580
7	0.0700	0.4780
8	0.0800	0.5000
9	0.0900	0.5210
10	0.1000	0.5430
11	0.1100	0.5650
12	0.1200	0.5850
13	0.1300	0.6070
14	0.1400	0.6280
15	0.1500	0.6490

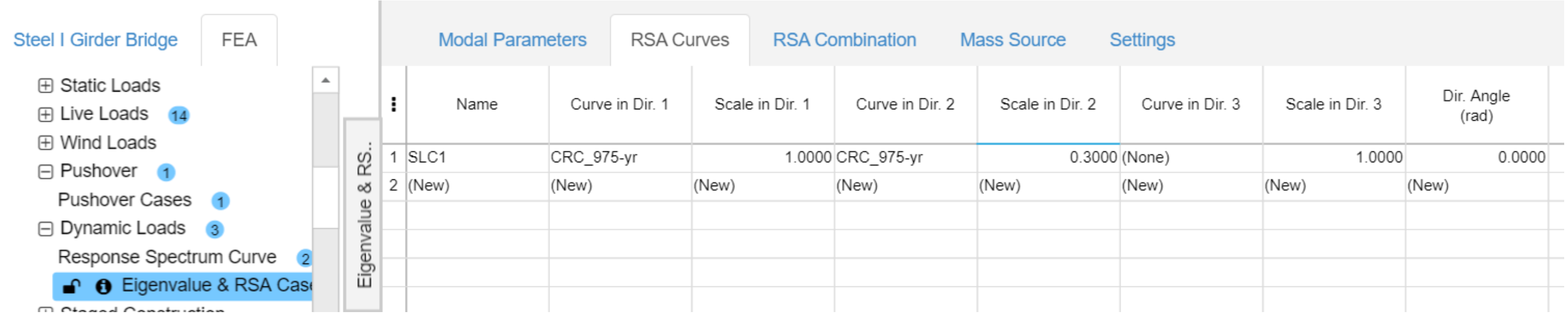


IBR Seismic Curve

2. Seismic Analysis - Capacity



	Name	Reference Node	Reference Direction	Reference Displacement (in)	Max # of Steps	Initial Load Factor	Load Factor Increment
1	PUSH1	(None)	TX	1.0000	1.0000	1.0000	1.0000
2	(New)	(New)	(New)	(New)	(New)	(New)	(New)

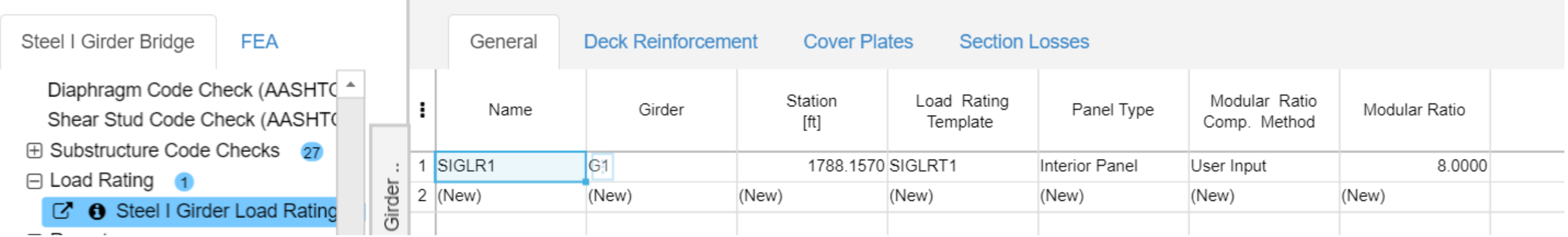


	Name	Curve in Dir. 1	Scale in Dir. 1	Curve in Dir. 2	Scale in Dir. 2	Curve in Dir. 3	Scale in Dir. 3	Dir. Angle (rad)
1	SLC1	CRC_975-yr	1.0000	CRC_975-yr	0.3000	(None)	1.0000	0.0000
2	(New)	(New)	(New)	(New)	(New)	(New)	(New)	(New)

3. Load Rating

- The Design Model in OpenBrIM can also perform the Load Rating Analysis.

- The OpenBrIM Workflow makes it possible to deliver the design model to the owner for Load Ratings



V. **LOD 400 Models**

1. 3D Models for Fabrication Coordination
2. Digital Twins – Asset Management Models

1. 3D Models for Fabrication Coordination

STRUCTURE magazine | Efficient Steel Bridge Design & Construction Using Collaborative Fabrication Models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Efficient Steel Bridge Design & Construction Using Collaborative Fabrication Models

Oct, 2023 By Douglas J. Dunrud P.E. In Structural Collaboration

WSP is using OpenBrIM to model steel girder bridges with improved efficiency and accuracy.

Blueprints, like cassette tapes and Blockbuster Video are now relics of the past. The transportation infrastructure industry must undergo a similar paradigm shift to make use Building Information Models (BIM) that have the potential to make bridge design more accurate, fast and dynamic.The Federal Highway Administration (FHWA) is leading an effort entitled BIM for Infrastructure that enables users to exchange data from one discipline to the next, indicating who is building what, when each part will be built, the materials to be used, and how it will be constructed.

Typical transportation infrastructure projects use roadway design software such as Bentley OpenRoads Designer or Autodesk Civil 3D for creating the roadway geometry. Recently, WSP began using the software platform OpenBrIM for the digital deliver these bridges with a dynamic link to the roadway geometrics. This model-centric workflow using OpenBrIM will provide dramatic improvements in both efficiency and consistency in delivering the traditional deliverables of plans and quantities, but this is only the beginning of the advantages of the 3D bridge models. This article is focused on the potential advantages of using collaborative design and fabrication models in lieu of the traditional workflow process, as shown in Figure 1.

Figure 1 Traditional vs collaborative shop drawing workflow.

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1. 3D Models for Fabrication Coordination

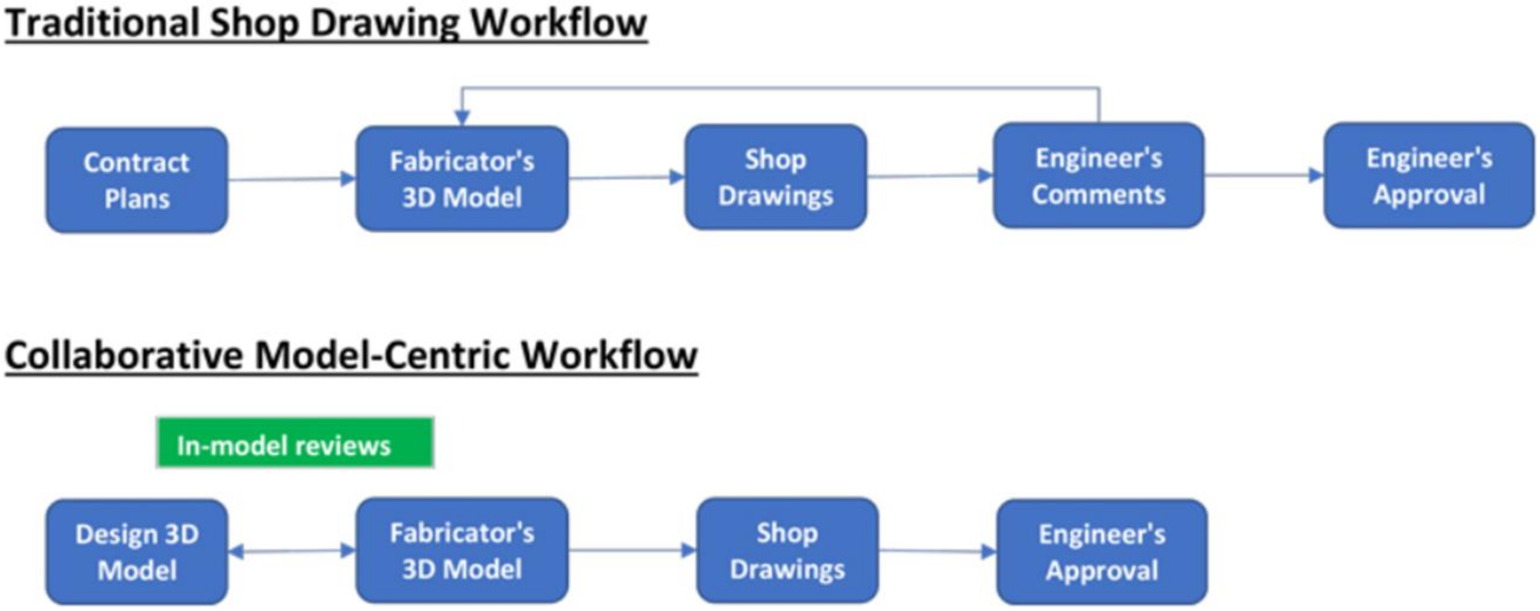
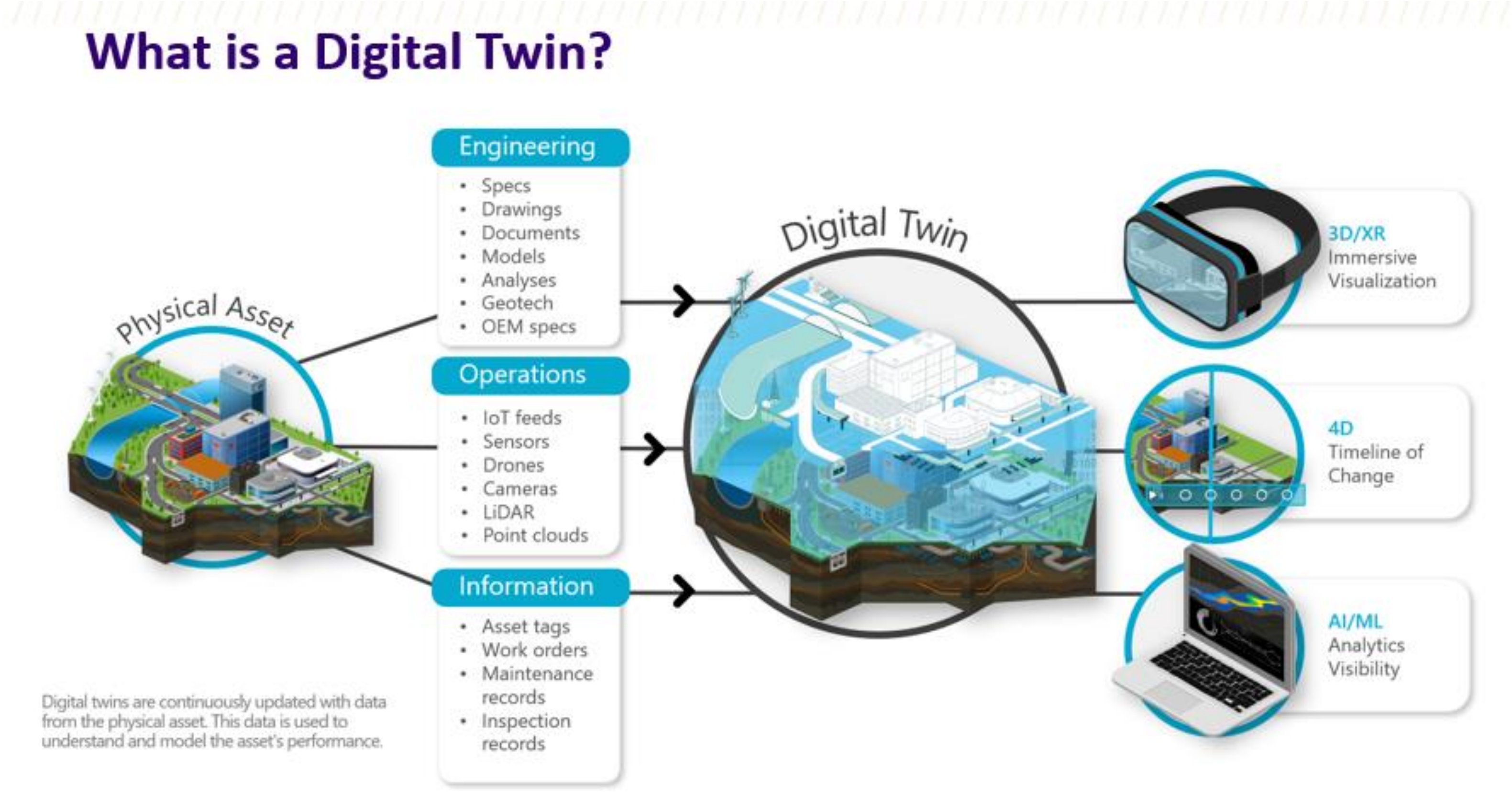


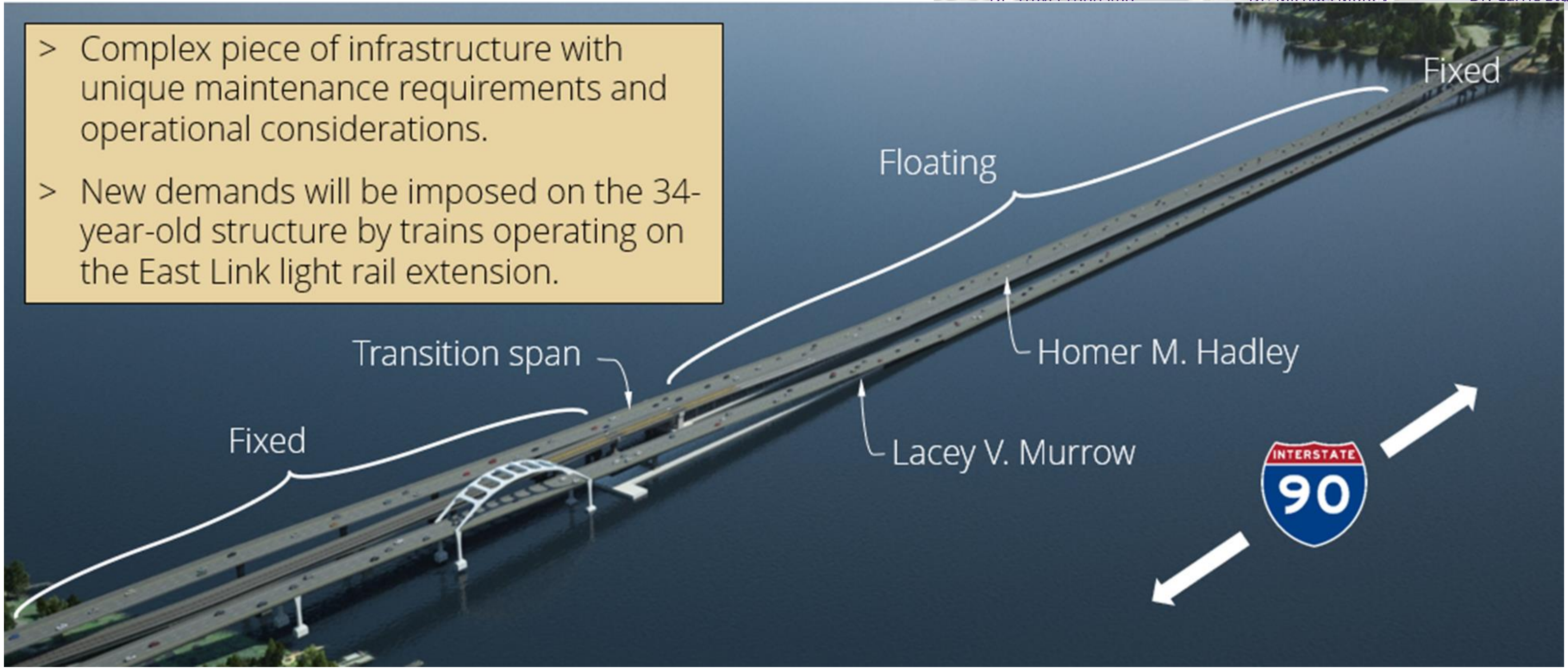
Figure 1 Traditional vs collaborative shop drawing workflow.

2. Digital Twins – Asset Management Models



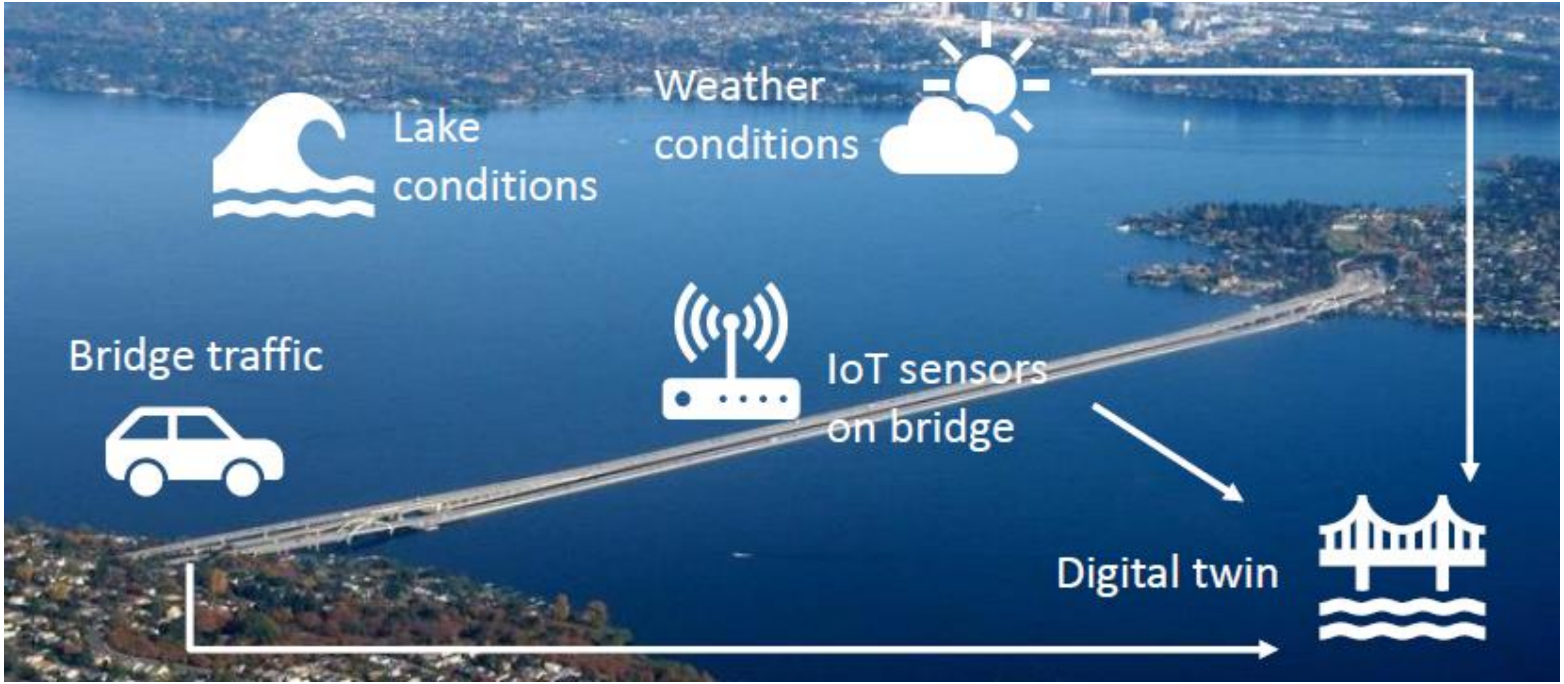
2. Digital Twins – Asset Management Models

Homer M. Hadley Memorial Bridge



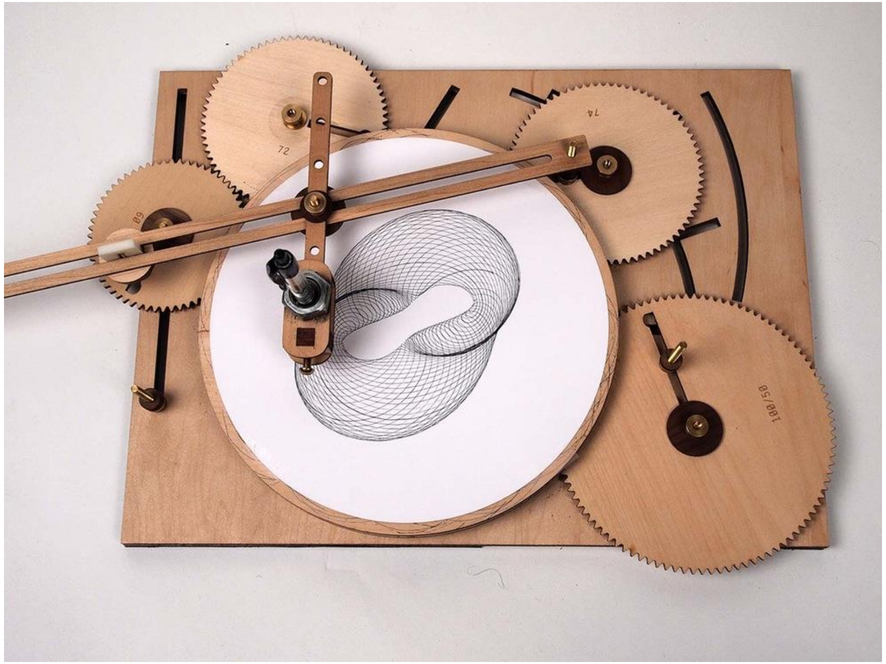
2. Digital Twins – Asset Management Models

Evaluate the benefits, limitations, and tradeoffs that an agency or agencies could expect when using similar technologies for asset management, maintenance, and operations



Conclusion:

It does not make sense to do Conceptual Design using traditional methods (ie CAD only) and it is a shame to not use the models for the final deliverables.



Thank you!
Questions?

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