FHWA Update

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BrM User Group Meeting

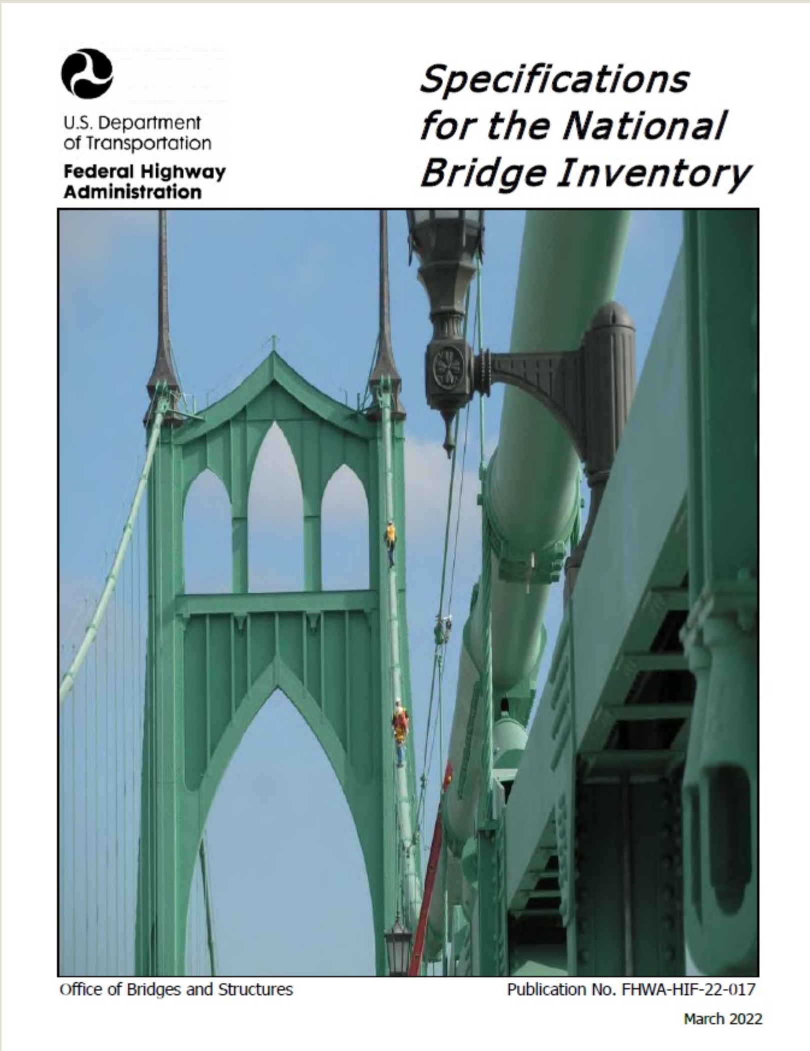
September 19, 2023
Boise, Idaho

U.S. Department of Transportation
Federal Highway Administration
Office of Infrastructure

Outline

- Update on Specifications for the National Bridge Inventory (SNBI) implementation
- FHWA Project Summary – Conversion Profiles for Element and Component Condition

SNBI Implementation Update



- Data that is reported for qualifying bridges (23 CFR 650.303)
- Published on May 6, 2022
- Replaces the FHWA Recording and Coding Guide
- Last major update in 1995
- https://www.fhwa.dot.gov/bridge/snbi.cfm

SNBI Implementation Schedule

U.S. Department of Transportation
Federal Highway Administration

Memorandum

Subject: **ACTION:** Implementation of the Specifications for the National Bridge Inventory
Date: May 25, 2022
In Reply Refer To: HIBS-30

From: Joseph L. Hartmann, Ph.D., P.E.
Director, Office of Bridges and Structures

JOSEPH LAWRENCE HARTMANN
Digitally signed by JOSEPH LAWRENCE HARTMANN
Date: 2022.05.25 13:38:04 -04'00'

To: Division Administrators
Federal Lands Highway Division Directors

Purpose

The purpose of this Memorandum is to outline the process by which the Federal Highway Administration (FHWA) will transition the data reported to the National Bridge Inventory (NBI) from alignment with the *Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation's Bridges* (Coding Guide) to the *Specifications for the National Bridge Inventory* (SNBI). Implementation of the SNBI will necessitate development of new database systems, updates to procedures, and training for inspectors and database managers, among other actions. This Memorandum specifically addresses the requirements[1] associated with data collection and submittal activities before, during, and after the transition period to the SNBI. Details of the transition process and associated data collection and submittal requirements are outlined below.

Background

FHWA provides oversight of highway bridge safety by implementation of the National Bridge Inspection Standards (NBIS), which are required by statute (23 U.S.C. 144) and defined in regulation (23 CFR part 650 Subpart C). An update to the NBIS was published in the Federal Register on May 6, 2022.

The SNBI was developed in coordination with the update to the NBIS regulation, the American Association of State Highway and Transportation Officials (AASHTO) Manual for Bridge Evaluation (MBE), the AASHTO Manual for Bridge Element Inspection (MBEI), and the FHWA Bridge Inspector's Reference Manual (BIRM). The SNBI is incorporated by reference in 23 CFR 650.317 and provides the specifications for reporting data for highway bridges open to the public to FHWA for inclusion in the NBI. The SNBI supersedes the Coding Guide. FHWA is developing an updated database system (NBI NextGen) to accommodate the data changes inherent to the SNBI and modernize the data submittal and validation process, while retaining the legacy data collected in accordance with the Coding Guide.

[1] 23 CFR 650.315

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- Reference May 25, 2022, Memo Implementation of the Specifications for the National Bridge Inventory
- Outlines transition from Coding Guide to SNBI including the start date for reporting data and availability of supporting FHWA systems and resources
- https://www.fhwa.dot.gov/bridge/pubs/Memo-Implementation_Specifications_National_Bridge_Inventory_FINAL.pdf

SNBI Implementation Schedule

Timeline (from Memo Implementation of the Specifications for the National Bridge Inventory)

Target Date	Action
May 2022	NBIS and SNBI published
July 2022	FHWA publishes Data Crosswalk
October 2022	FHWA publishes Data Submittal Schema and Data Submittal Validation Logic (Initial Version)
April 2023	Transition Tool is made available online
October 2024	FHWA makes NBI NextGen available online for data validation only
March 15, 2025	Last NBI data submittal in accordance with 1995 Coding Guide
January 1, 2026	**Last date to begin** verification of transitioned data and collection of SNBI-based data for inspected bridges – Agencies may elect to begin SNBI-based data collection and verification earlier to meet the March 15, 2028, deadline for submittal of a complete SNBI-based NBI dataset
January 1, 2026	FHWA makes NBI NextGen available for Data Submittals

SNBI Implementation Schedule

Timeline (cont.)

March 15, 2026	First SNBI-based NBI data submittal – Transitioned/Hybrid Dataset – At a minimum, all bridges submitted with transitioned data except for specified fields required to manage FHWA programs, which shall be collected or verified in accordance with the SNBI – Continue verification of transitioned data and collection of SNBI-based data
June 2026	Transition Tool sunsets
March 15, 2027	Second SNBI-based NBI data submittal – Transitioned/Hybrid Dataset – Continue verification of transitioned data and collection of SNBI-based data
March 15, 2028	Third SNBI-based NBI data submittal – 100% populated and verified – No temporary codes permitted – First complete SNBI-based dataset with collected and verified SNBI-based data for all bridges

SNBI Implementation Resources

- Now available at https://www.fhwa.dot.gov/bridge/nbi.cfm
  - FHWA Data Transition Logic (crosswalk)
    - Mapping between items and codes of the Coding Guide and SNBI
  - Data transition tool
  - Data submittal schema
  - Data submittal validation logic (part A)
  - Questions and answers
- Training now available (contact your FHWA Division Office)

SNBI Implementation Resources

- In Development
  - New NBI System
  - Data submittal validation logic (part B)
  - Online data submittal checker
  - SNBI errata

SNBI Implementation Update

- Planned Errata
  - Technical corrections and clarifications
  - Responsive to email questions that identified discrepancies or sought clarification
    - Latitude and longitude alignment with HPMS
    - Handling of state-defined legal load rating vehicles
    - Routine Permit Loads item coding

SNBI Implementation Update

- Planned Errata
  - Latitude and longitude alignment with HPMS

Latitude

Format	Frequency
N (9,6)	I

Specification	
Report the latitude of the bridge in decimal degrees. Report the latitude at the same location as the LRS mile point reported for Item B.H.07 *(LRS Mile Point)*. If the location of the LRS mile point is not known, report the latitude at the location of the bridge following agency procedures.	Values approp… consis… Ameri… When available, HPMS data should be used to update NBI items values.

Examples

Planned errata:
Report the latitude at the location of the bridge following agency procedures.

SNBI Implementation Update

- Planned Errata
  - Handling of state-defined legal load rating vehicles

SUBSECTION 5.3: LOAD EVALUATION AND POSTING

The data items in this subsection provide information on the load carrying capacity of the bridge with respect to the legal load configurations established by AASHTO. These data items are considered part of the Posting Evaluation Data Set and have a many-to-one relationship with a bridge when applicable.

Data items in this subsection are reported for each AASHTO legal load configuration evaluated, only when the bridge has undergone a posting analysis. The data for these items may change after reevaluation of the load rating.

The following data items are included in this subsection.

Item ID	Data Item
B.EP.01	Legal Load Configuration
B.EP.02	Legal Load Rating Factor
B.EP.03	Posting Type
B.EP.04	Posting Value

many-to-one dataset

SNBI Implementation Update

- Planned Errata
  - Handling of state-defined legal load rating vehicles

5.3 – LOAD EVAL

Legal Load Configuration

Format	Frequency
AN (3)	I

Specification	Comm
Report the configuration of the AASHTO legal load using one of the following codes.	Refer to the AASHTO M Evaluation for details c configurations.
	For information on the posting of emergency November 3, 2016 FHV http://www.fhwa.dot.g 61103.cfm

Code	Description
3	Type 3
3S2	Type 3S2
3-3	Type 3-3
SU4	SU4 truck
SU5	SU5 truck
SU6	SU6 truck
SU7	SU7 truck
NRL	Notional Rating Load
EV2	Type EV2 emergency vehicle
EV3	Type EV3 emergency vehicle

Planned errata:
Add

Code	Description
A##	State-defined legal load

Replace the ## characters in the A## code with sequential numbers, with leading zeros, starting with A01, and assigned to each State-defined legal load configuration. Use consistent designations for all bridges in a State.

SNBI Implementation Update

- Planned Errata
  - Routine Permit Loads item coding

Code	Description
A	Bridge carries routine permit loads. Load capacity is adequate for all routine permit loads; no routine permit loads are restricted.
B	Bridge carries routine permit loads. Load capacity is adequate for some routine permit loads but some routine permit loads are restricted.
C	Bridge does not carry routine permit loads. Routine permit loads are restricted from the bridge.
N	Bridge does not carry routine permit loads. Agency does not issue routine permits.

SNBI Implementation Update

- Email question box

NBIS_SNBI_Questions@dot.gov

FHWA Conversion Profiles Project

Purpose:

- Develop new and refined profiles for converting element condition states to component condition ratings

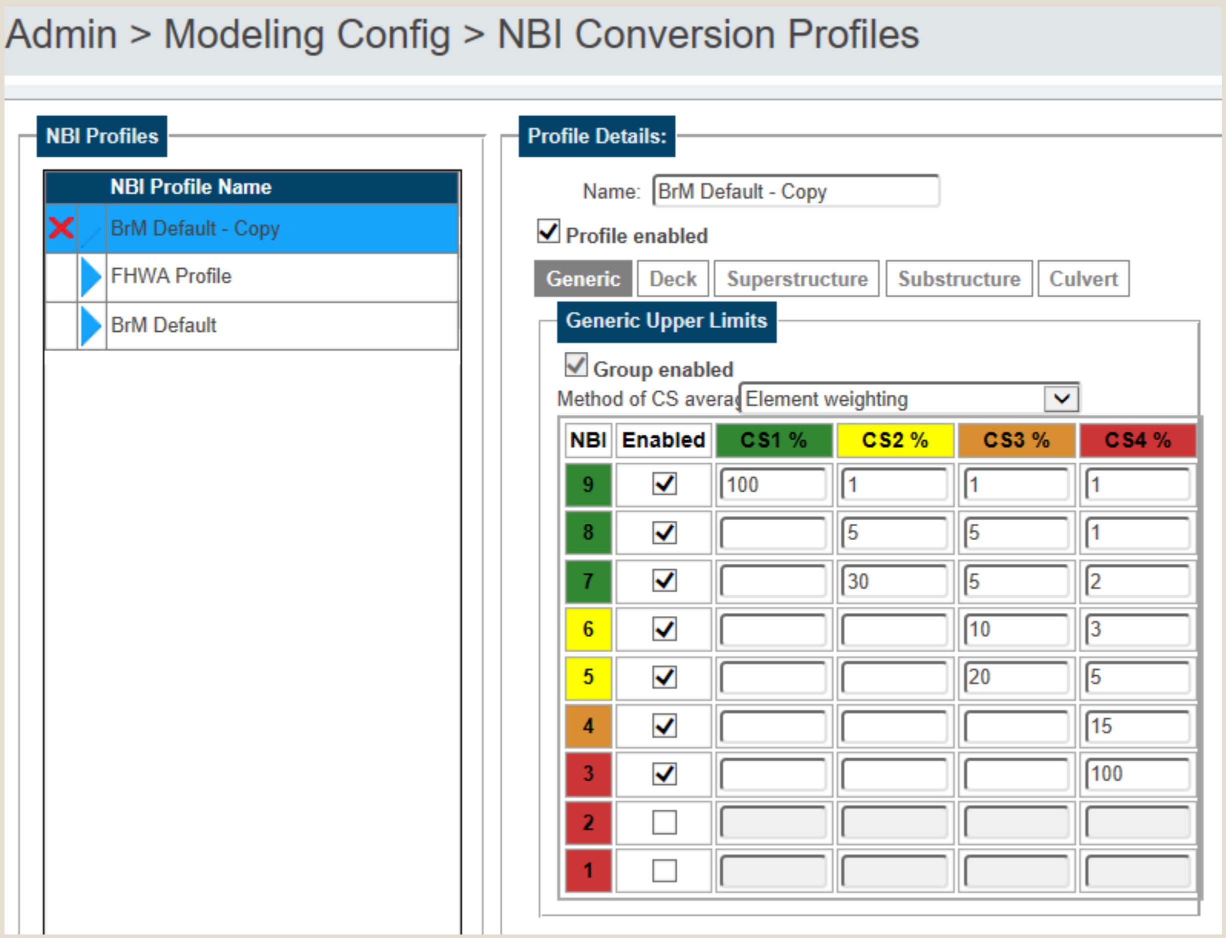
FHWA First Generation Universal Profile
for Manual for Bridge Element Inspection Data

NBI Condition Limits

NBI	CS1 %	CS2 %	CS3 %	CS4 %
9	x	x	x	X
8	100	0	0	0
7		1 - 20	0	0
6			1 - 5	0
5			6 - 20	0
4				1 -20
3				21-100
2	x	x	x	X
1	x	x	x	X

FHWA Conversion Profiles Project

AASHTOWare™ BrM Universal Profile



FHWA Conversion Profiles Project

<u>Scope</u>:

- Update existing FHWA universal profile
- Develop profiles for each component type (4 profiles)
- Develop profiles for common component + material types (>20 profiles)
- Prepare documentation that describes development process and final selected profiles
- Develop spreadsheet program that applies the selected profiles on NBI files and individual bridges

FHWA Conversion Profiles Project

Contractor:

- Wiss, Janney, Elstner Associates, Inc. (WJE)

Status:

- 2024 publishing (estimated)

FHWA Conversion Profiles Project

Why is FHWA sponsoring this project?

- Support Transportation Performance Management
- Support element-level bridge management
- Support inspection data quality review
- Support the FHWA NBIAS* software application (forecasts future conditions and needs for biennial reporting to Congress)

*National Bridge Investment Analysis System

FHWA Conversion Profiles Project

Process Summary:

Data Processing

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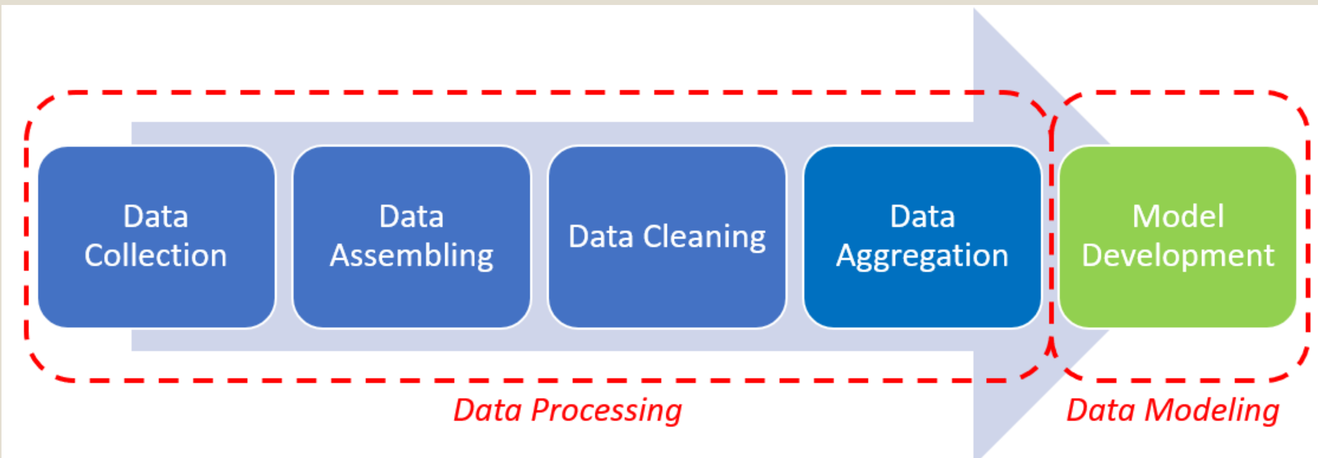
Data Analysis

FHWA Conversion Profiles Project

Data Processing:

- Step 1: Data collection (acquisition and storage)
- Step 2: Data assembling (joining)
- Step 3: Data cleaning (censoring)
- Step 4: Data aggregation of multi-element components



FHWA Conversion Profiles Project

Data Analysis

- Evaluated different techniques for developing optimal performing profiles
- Evaluated different definitions for performance (accuracy metrics)
- Evaluated different procedures for data aggregation of multi-element components

Data Processing

Step 1 - Data collection (acquisition and storage)

- Data source is publicly available NBI processed files
- Element data for all NHS bridges not reported until ≈ April 2017.
  - Reporting started in April 2015.
  - Data reported in April 2015 and 2016 was a combination of migrated, field collected, and empty data.
  - State submittals included a response to the inventory-level question is the element data “migrated”, “field collected”, or “combination”.
- Project used 2017-2022 element data submittals excluding post 2016 submittals that answered data is “migrated” or “combination”.

Data Processing

Step 2 - Data assembling (joining)

- Inventory data needed joined with element data of same year (two different files)
- Unique identifiers used for each joined dataset are State Code, Structure Number, and Submittal Year
- Data reduced to items needed for developing profiles
  - essentially main and approach span types, deck type, component ratings, inspection dates, element types and condition states
- Fact table includes a created item for recording an error code during data cleaning

Data Processing

Step 2 - Data assembling (joining)

Fact table showing reduced dataset and identifiers

Bridge Keys		Element-level Fact Table			NBI Fact Table							Index
State Code (1)	Date of Data Submittal	Element Code/Parent Code	Total Quantity	CS1 Quantity	Component Name (D, SP, SU, Cul)	Routine Inspection Date (90)	Component Rating * (58-60, 62)	Type of Deck (107)	NHS or non-NHS (104)	Inspection Frequency (91)	Fracture Critical Inspection Date (93A)	Error Code
Structure Number (8)		CS2 Quantity	CS3 Quantity	CS4 Quantity	Type of Main Material (43A)	Type of Main Design (43B)	Approach – Type of Material (44A)	Approach – Type of Design (44B)	General Rating (G, F, P)	Underwater Inspection Date (93B)	Other special inspection Date (93C)	

** The component rating (deck, superstructure, substructure, culvert) will be selected based on the category to which the element belongs (according to Table 1).*

Data Processing

Step 3 - Data cleaning

- Fact table data was retained in project database but not all data used in profile development.
- Example data excluded from profile development;
  - Redundant condition data
    - Coincident submittals can convey conditions from the same inspection (does not represent separate inspection observations)
    - Excluded by counting one inspection observation (data row) for each routine inspection date
  - Bridges with different main and approach span material types
    - Component rating is not associated with one superstructure type and corresponding elements.
    - Difference in span continuity was not cause for exclusion.

Data Processing

Step 3 - Data cleaning

FHWA Coding Guide Item 43A Main Spans Material Type
(Item 44A Approach Span similar)

Item 43 - Structure Type, Main 3 digits

Record the description on the inspection form and indicate the type of structure for the main span(s) with a 3-digit code composed of 2 segments.

Segment	Description	Length
43A	Kind of material and/or design	1 digit
43B	Type of design and/or construction	2 digits

The first digit indicates the kind of material and/or design and shall be coded using one of the following codes:

Code	Description
1	Concrete
2	Concrete continuous
3	Steel
4	Steel continuous
5	Prestressed concrete *
6	Prestressed concrete continuous *
7	Wood or Timber
8	Masonry
9	Aluminum, Wrought Iron, or Cast Iron
0	Other

Data Processing

Step 3 - Data cleaning

Excluded bridges with main and approach material types that are outside the following ranges

Table 4. Main span vs. approach span material type

NBI 43A (Main Spans)	44A (Approach Spans)
1, 2	0*, 1, 2
3, 4	0, 3, 4
5, 6	0, 5, 6
7	0, 7
8	0, 8
9	0, 9

** This included all the elements designated as "0", "00", or "000".*

Table 5. NBI coding designation for items 43A and 44A

Code	Description
1	Concrete
2	Concrete continuous
3	Steel
4	Steel continuous
5	Prestressed concrete*
6	Prestressed concrete continuous*
7	Wood and timber
8	Masonry
9	Aluminum, Wrought Iron or Cast Iron
0**	Other
99	Miscoded data

Data Processing

Step 3 - Data cleaning

- Questionable data
  - Total element quantity equals 0
  - Element type does not match with main/approach span material type (items 43A & 44A) or deck type (item 107)
  - Component rating ≥ 7 and any element comprising the component has CS4 > 0%
  - Component rating < 7 and all elements comprising the component have CS1 = 100%

Data Processing

Step 3 - Data cleaning

FHWA Coding Guide Item 107 Deck Type

Item 107 - Deck Structure Type 1 digit

Record the type of deck system on the bridge. If more than one type of deck system is on the bridge, code the most predominant. Code N for a filled culvert or arch with the approach roadway section carried across the structure. Use one of the following codes:

Code	Description
1	Concrete Cast-in-Place
2	Concrete Precast Panels
3	Open Grating
4	Closed Grating
5	Steel plate (includes orthotropic)
6	Corrugated Steel
7	Aluminum
8	Wood or Timber
9	Other
N	Not applicable

Data Processing

NBI Deck Type and Deck Element Type Matches

Table 8. Deck structure type vs. deck element material types

NBI 107	Deck Element
1, 2	13,15,12,38,16
3, 4, 5, 6	28,29,30
8	31,54
7, 9, N	60,65

NBI Span Material Type and Superstructure Element Type Matches

Table 6. Main span vs. superstructure's elements material types

NBI 43A (Main Spans)	Superstructure Element
1, 2	105,110,116,144,155
3, 4	102,107,113,120,141,147,148, 152,161,162
5, 6	104,109,115,143,154
7	111,117,135,146,156
8	145
9, 0	106,112,118,136,142,149,157

Data Processing

Step 4 - Element aggregation (multi-element components)

- Profile development considered the condition of all elements comprising a multi-element component
  - NHS Deck components – approx. 95% are a single element type
  - NHS Superstructure components – approx. 90% are a single element type
  - NHS Substructure components – approx. 15% are a single element, 10% two elements, 50% three element types, remainder 4 or more elements
- Element aggregation resolves to evaluating the contribution of each element type on a component rating (<u>difficult proposition</u>)

Data Processing

Step 4 - Element aggregation (multi-element components)

- Evaluated 8 techniques
  - No aggregation
  - FHWA First Generation MBEI Data Profile (combination weighted and linear average)
  - Linear average
  - Linear average of lowest scored elements
  - Linear average of highest CS4 elements by normalized quantity
  - Linear average of highest CS4 elements by absolute quantity
  - Highest CS4 element by normalized quantity
  - Lowest scored element
- Data was processed using each aggregation technique for later use during data analysis

Data Processing

After processing completion;

- ≈1.4 million data rows (inspection observations) were available for data analysis.
- Each row representing a component rating and element condition states pair
- Some pairs represented the individual elements of multi-element components

FHWA Conversion Profiles Project

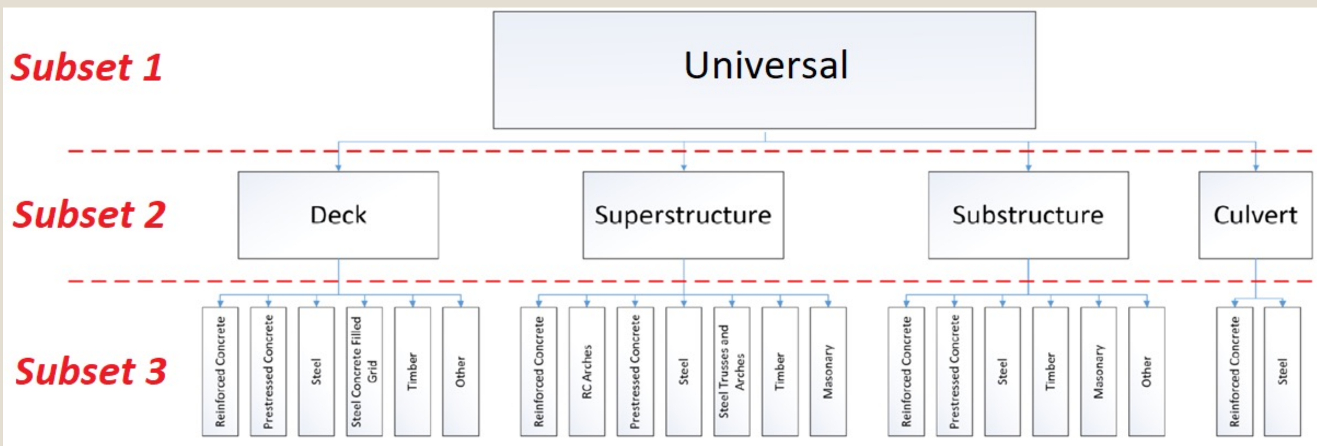
<u>Data Analysis:</u>

Profile development;

- Evaluated different techniques for developing optimal performing profiles
- Evaluated different definitions for performance (accuracy metrics)
- Evaluated the different techniques for data aggregation of multi-element components

Data Analysis

- Project end goal was to develop ≈26 profiles as shown in diagram

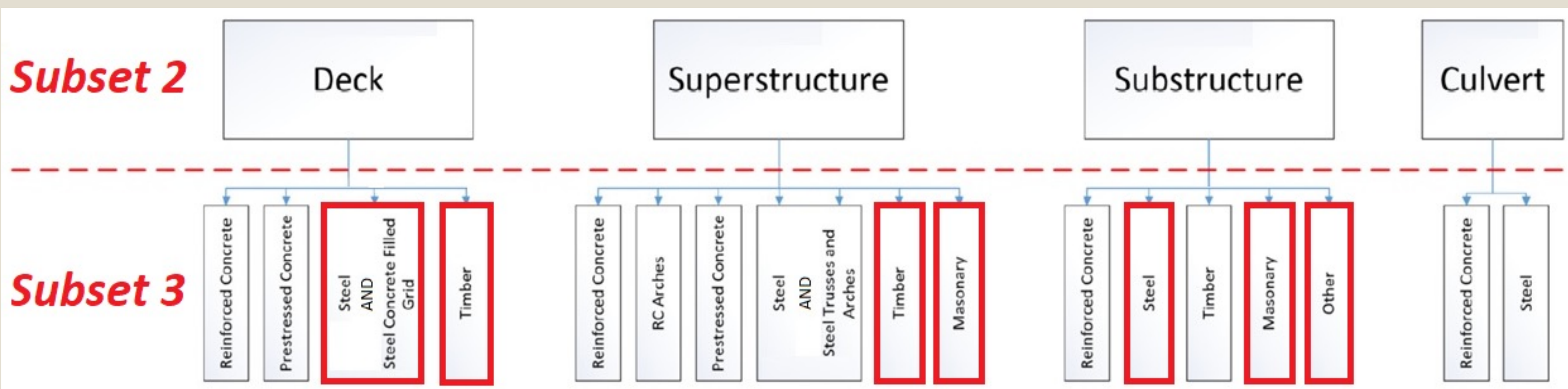


Data Analysis

- After application of the profile development techniques it was found that some population sizes were insufficient to develop convergent profiles.
- Some component + material type population sizes are relatively small.
- Need sufficient data across all component ratings (3-9) for a component + material type.
  - Finding: rule of thumb need at least 1,000 inspections for each component + material type.
- Developed 22 profiles

Data Analysis

- Developed conversion profiles
  - 22 profiles, universal profile not shown
  - Profiles in bold border were developed from less than 1,000 inspections



Data Analysis

Profile development techniques:

- Uses software applications that identify the <u>**best fit**</u> profile ("optimization algorithms or programming").
- <u>**Best fit does not always mean best performing**</u> (will describe later)
  - best fit is based on optimization objective function
  - best performing can be based on a user's accuracy metric
- Evaluated techniques:
  - Logistic regression
  - Classification decision tree
  - Machine learning and artificial intelligence
  - Accuracy also compared with existing profiles

Data Analysis

Profile development techniques

- Logistic regression
  - Uses a logistic function to model a binary dependent variable
  - A statistical procedure to find the best fit for a set of independent variables (condition states) versus dependent variable (component rating) by minimizing the sum of the offsets from actual value

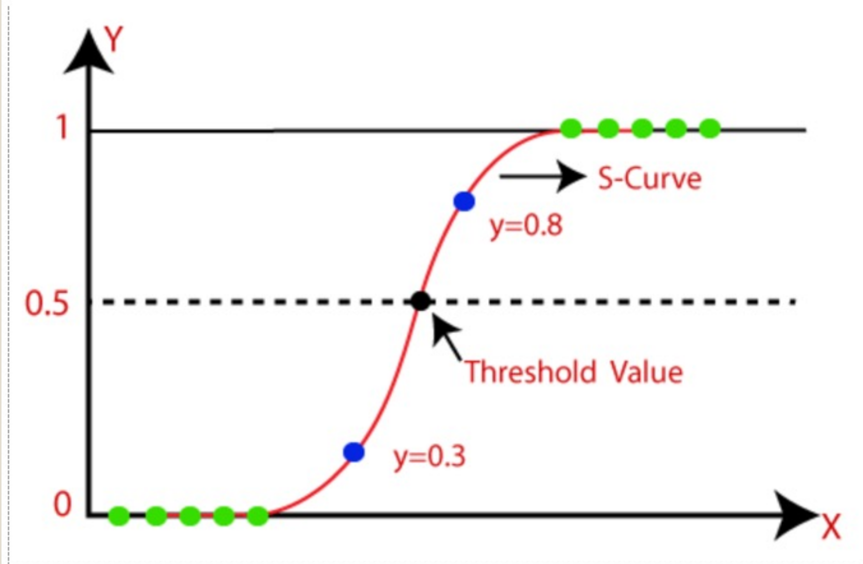
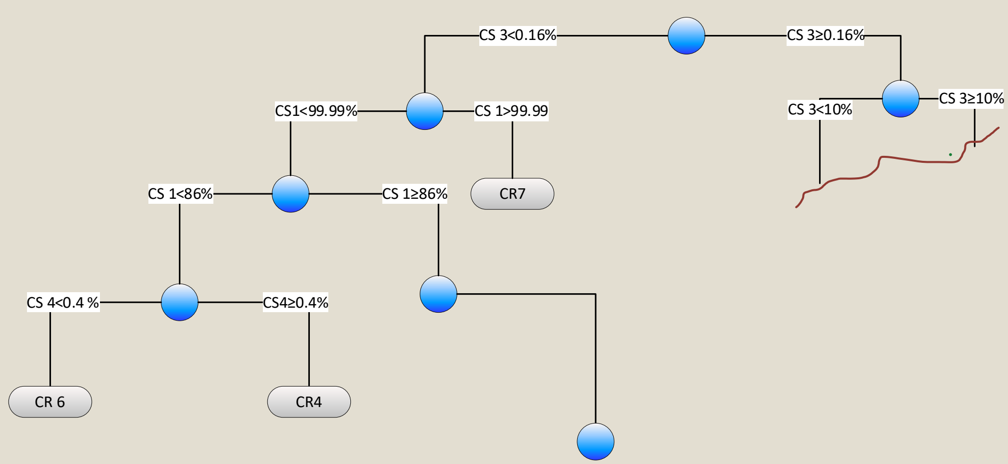


Figure 13. Conceptual definition of a Logit Model

Data Analysis

Profile development techniques

- Classification decision tree
  - Supervised machine learning algorithm
  - Breaks dataset into smaller and smaller subsets or branches
  - Performance is dependent on the number of selected branches (input constraint)
  - Project selected 20 branches maximum. Found insignificant performance improvement beyond 20 branches and profile would be less efficient for manual use and programming.



Data Analysis

Profile development techniques

- Machine learning and artificial intelligence
  - Evaluated K-Nearest Neighbors (KNN), Support Vector Machine (SVM), Discriminant.
  - "Black box" techniques that did not align with the project objectives.
    - Wanted profiles that can be developed using a repeatable technique.
    - Wanted profiles that could be applied manually.

Data Analysis

Definitions for performance (accuracy metrics):

- For identifying which profile development and aggregation techniques performed best.
- Want the most accurate profile, but how do you define accuracy?
  - Highest percentage of converted values that are within ±0 of actual value?
  - Highest percentage of converted values that are within ±1 of actual value?
  - Other?

Data Analysis

Definitions for performance (accuracy metrics)

- Initial results we were showing that the best performing. profiles were emphasizing accuracy within the most common component condition ratings and sacrificing accuracy within the least common condition ratings.
  - Which are the most common component ratings?
  - Which are the least common component ratings?
    - Most common are 6-7 range.
    - Least common are 3-4 range.

Data Analysis

Definitions for performance (accuracy metrics):

- Component ratings are not a random variable … each value on a 0-9 scale does not have equal likelihood of occurring in an inventory.
  - Its an **"imbalanced dataset"** … inspection datasets are not distributed relatively equally across all condition ratings.
- Project added data sampling and accuracy metrics to address the imbalanced dataset issue.

Data Analysis

Profile development:

Original data sampling technique – **whole sample profile population**

Added data sampling technique – **under sample profile population**

- **Under sampling to a condition rating**.
  - Balances or partially balances a population by limiting the sample from each condition rating to a number equal to the size of a selected condition rating.
    - Reduces datapoints used for profile development but removes optimization bias.
  - **Decided to under sample to condition rating 4**
    - low end of population counts.
    - gives equal weight to achieving accurate conversions for rating 4 (important to owners because rating 4 influences major decisions - long range planning, project programming, costly work actions, etc.).

Data Analysis

Accuracy comparison imbalanced and balanced by under sampling to CR4

Total Accuracy ±0

Deck Component – Reinforced Concrete Material

Table 14. Summary of Total Accuracy Results (Based on 20% of Testing Dataset) with Confidence Level **±0 CR Margin of Error** - Deck Component/ Profile (All-Element)

Aggregation Methods	Modeling Techniques			
	FHWA	Log. Reg.	DT#1 (imbalanced)	DT#2 (under CR4)
0- No Aggregation	46	51	54	44
I- FHWA	46	51	54	44
II- Lin. Ave. of All	46	51	55	44
III- Lin. Ave. of Lowest Score	46	51	54	44
IV- Lin. Ave. of Highest CS4%	46	51	54	45
V- Lin. Ave. of Highest CS4(Qu.)	46	51	55	45
VI- Highest CS4%	46	51	54	45
VII- Lowest Score	46	52	54	45

Data Analysis

Accuracy comparison imbalanced and balanced by under sampling to CR4

Accuracy by Condition Rating ±0

RC Deck Component – Decision Classification tree - No Aggregation

		CR3	CR4	CR5	CR6	CR7	CR8	CR9	Total All Elements
Imbalanced	# of Elements Converted Accurately	14	0	6509	25055	64879	3	0	178173
	Accuracy	4%	0%	33%	52%	77%	0%	0%	54%
Under Sample to CR4	# of Elements Converted Accurately	0	2378	1497	751	1090	650	2572	20180
	Accuracy	0%	72%	45%	23%	33%	20%	78%	44%

Data Analysis

Definitions used for performance evaluation (accuracy metrics):

- Original metrics - **Total accuracy**
  - Total % across ratings with converted values ±0 of inspection value
  - Total % across ratings with converted values ±1 of inspection value
- Added metrics – **Accuracy in select condition ratings**
  - For inspection values 4-5: the % of converted values ±0 of inspection value
  - For inspection values 4-7: the % of converted values ±0 of inspection value
  - "Ranking Score" (weighted combination of preceding bullets)
- Regardless of metrics used for evaluation, all optimization objective functions used total accuracy ±0

Data Analysis

Definitions used for performance evaluation (accuracy metrics)

Accuracy and Ranking Metrics

$$Total\ Accuracy\ \pm 0\ CR = \frac{\sum_{i=3}^{9}(\pm 0\ Correctly\ Predicted_{CRi})}{\sum_{i=3}^{9} Total_{CRi}}$$

$$Total\ Accuracy\ \pm 1\ CR = \frac{\sum_{i=3}^{9}(\pm 1\ Correctly\ Predicted_{CRi})}{\sum_{i=3}^{9} Total_{CRi}}$$

$$Total\ Accuracy\ \pm 2\ CR = \frac{\sum_{i=3}^{9}(\pm 2\ Correctly\ Predicted_{CRi})}{\sum_{i=3}^{9} Total_{CRi}}$$

$$Sum(CR4-5)_{\pm 0} = \frac{\sum_{i=4}^{5}(\pm 0\ Correctly\ Predicted_{CRi})}{\sum_{i=4}^{5} Total_{CRi}}$$

$$Sum(CR4-7)_{\pm 0} = \frac{\sum_{i=4}^{7}(\pm 0\ Correctly\ Predicted_{CRi})}{\sum_{i=4}^{7} Total_{CRi}}$$

$$Ranking\ Score = 1.0 \times Sum(CR4-5)_{\pm 0} + 0.4 \times Sum(CR4-7)_{\pm 0}$$

Data Analysis

Number of alternative profiles developed for evaluation:

- 2 data sampling methods (balanced and imbalanced) and 8 aggregation techniques = 16 alternative profiles for each end goal profile type
- 16 x 22 end goal profile types = 352 alternative profiles for each profile development technique
  - 352 for decision classification tree
  - 352 for logistic regression
  - plus some
- >700 alternatives developed for evaluation

Data Analysis

Number of alternative profiles developed for evaluation:

- Each profile was developed using an objective function that maximizes total accuracy (maximize total percentage across ratings with converted values that are within ±0 of actual value)

Data Analysis

Final profile selection:

- Evaluation and selection decisions:
  1. Optimization technique – decision classification tree or logistic regression
  2. Sampling technique – imbalanced, balanced by under sampling to CR4, or both
  3. Aggregation technique for multi-element components – 8 techniques evaluated

Data Analysis

Final profile selection:

Optimization technique: **Selected decision classification tree**

- Demonstrated better total accuracy and accuracy within individual condition ratings compared to logistic regression
- Simplicity in display format, manual use, and programming for automated use

Data Analysis

Final profile selection:

Sampling technique: **Selected both imbalanced and balanced by under sampling to CR4**

- Imbalanced provides best total accuracy across whole range of condition ratings
- Balanced by under sampling to CR4 provides more uniform accuracy across whole range of condition ratings
  - Lower total accuracy but more uniform across range of condition ratings (including lower ratings)
- User can pick profiles from either sampling technique

Data Analysis

Final profile selection:

Aggregation technique for multi-element components:

- There was not a consistent best performing aggregation technique across all profile types
- Aggregation technique did not appear very impactful to accuracy
- Still deciding whether to select best performing for each end goal profile type or best for each component type and apply the same to the component + material types

Data Analysis

Final profile selection:

Aggregation technique for multi-element components:

- Selected technique with highest total accuracy ± 0 for imbalanced sampling technique profiles

$$Total\ Accuracy\ \pm 0\ CR = \frac{\sum_{i=3}^{9}(\pm 0\ Correctly\ Predicted_{CRi})}{\sum_{i=3}^{9} Total_{CRi}}$$

- Selected technique with highest "Ranking Score" for balanced by under sampling to CR4 profiles

$$Ranking\ Score = 1.0 \times Sum(CR4-5)_{\pm 0} + 0.4 \times Sum(CR4-7)_{\pm 0}$$

Data Analysis

Final profile selection:

Summary:

- Selected two profiles for each end goal profile type –
  - One profile is based on sampling and aggregation technique that yields best total accuracy across whole range of condition ratings
    - normally very good accuracy near CR6-7 and poor accuracy near CR4
  - One profile is based on sampling technique that yields more uniform accuracy across range of condition ratings and aggregation technique that yields has best accuracy across range CR4-5.
  - **44 total profiles**

FHWA Conversion Profiles Project

Summary total accuracy table*

B ≡ under sampling to CR4
IB ≡ imbalanced sampling

ID	Subset	Component	Material	Modeling	Aggregation	Validation	Total Accuracy (±0CR)
1	1	All	All	B			
2				IB	Case II	80/20	/53%
3	2	Deck	All	B	Case IV	80/20	/45%
4				IB	Case I	80/20	/54%
5	2	Superstructure	All	B	Case I	80/20	/46%
6				IB	Case II	80/20	/50%
7	2	Substructure	All	B	Case III	80/20	/45%
8				IB	Case II	80/20	/55%
9	2	Culvert	All	B	Case V	80/20	/47%
10				IB	Case I	80/20	/58%

*(1) Balanced (B) profiles total accuracy values reflect aggregation technique that has highest value for using the ranking score metric.
(2) For simplicity, all final selected profiles may use best performing aggregation technique average by component (on average) rather than by component + material.

FHWA Conversion Profiles Project

Summary total accuracy table

ID	Subset	Component	Material	Modeling	Aggregation	Validation	Total Accuracy (±0CR)
1				B			
2	1	All	All	IB	Case II	80/20	/53%
3				B	Case IV	80/20	/45%
4	2	Deck	All	IB	Case I	80/20	/54%
5				B	Case I	80/20	/46%
6	2	Superstructure	All	IB	Case II	80/20	/50%
7				B	Case III	80/20	/45%
8	2	Substructure	All	IB	Case II	80/20	/55%
9				B	Case V	80/20	/47%
10	2	Culvert	All	IB	Case I	80/20	/58%
11				B	Case VII	80/20	/62%
12	3	Deck	Prestressed Concrete	IB	Case I	80/20	/66%
13				B	Case V	80/20	/45%
14	3	Deck	Reinforced Concrete	IB	Case V	80/20	/55%
15				B	Case III	80/20	/69%
16	3	Deck	Steel & Steel Concrete Filled Grid	IB	Case 0	80/20	/67%
17				B	Case VI	80/20	/60%
18	3	Deck	Timber	IB	Case VII	80/20	/79%
19				B	Case III	80/20	/68%
20	3	Superstructure	Reinforced Concrete	IB	Case I	80/20	/63%
21				B	Case IV	80/20	/46%
22	3	Superstructure	RC Arches	IB	Case IV	80/20	/55%

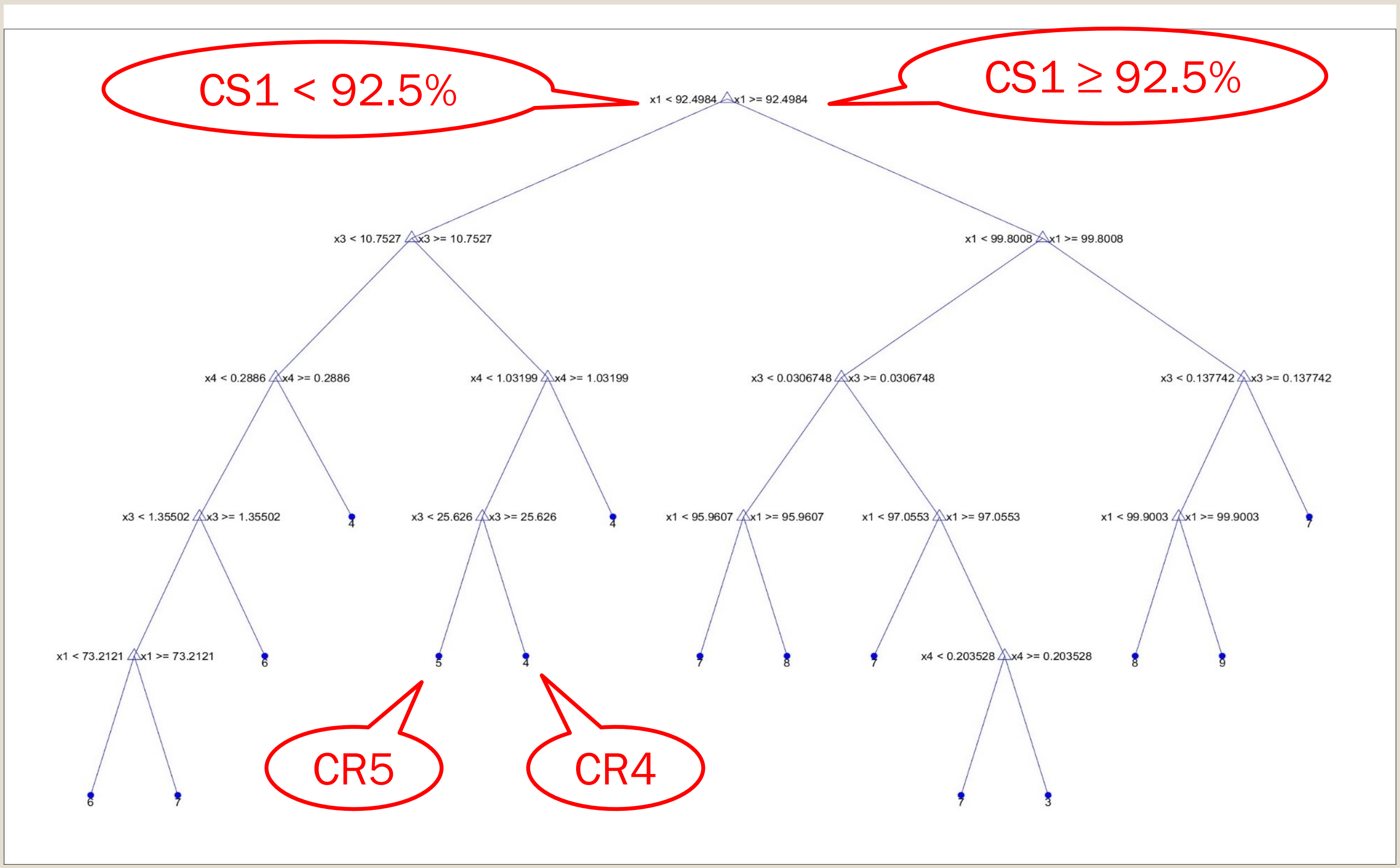
FHWA Conversion Profiles Project

Summary total accuracy table

ID	Subset	Component	Material	Modeling	Aggregation	Validation	Total Accuracy (±0CR)
23	3	Superstructure	Prestressed Concrete	B	Case VI	80/20	/52%
24				IB	Case I	80/20	/58%
25	3	Superstructure	Steel & Steel Trusses and Arches	B	Case III	80/20	/47%
26				IB	Case VI	80/20	/50%
27	3	Superstructure	Timber	B	Case III	80/20	/68%
28				IB	Case V	80/20	/64%
29	3	Superstructure	Masonry	B	Case IV	80/20	/81%
30				IB	Case IV	80/20	/77%
31	3	Substructure	Reinforced Concrete	B	Case VII	80/20	/43%
32				IB	Case I	80/20	/56%
33	3	Substructure	Steel	B	Case II	80/20	/80%
34				IB	Case III	80/20	/65%
35	3	Substructure	Timber	B	Case IV	80/20	/60%
36				IB	Case VI	80/20	/69%
37	3	Substructure	Masonry	B	Case IV	80/20	/62%
38				IB	Case VI	80/20	/69%
39	3	Substructure	Other	B	Case 0	80/20	/60%
40				IB	Case III	80/20	/57%
41	3	Culvert	Reinforced Concrete	B	Case 0	80/20	/46%
42				IB	Case IV	80/20	/58%
43	3	Culvert	Steel	B	Case 0	80/20	/57%
44				IB	Case III	80/20	/56%

FHWA Conversion Profiles Project

- Example profile (for substructure component balanced by under sampling to CR4)



QUESTIONS?