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Decision Tool for Prioritizing Bridge Repair or Replacement

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DECISION TOOL FOR PRIORITIZING BRIDGE REPAIR OR REPLACEMENT

by

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ABSTRACT

DECISION TOOL FOR PRIORITIZING BRIDGE REPAIR OR REPLACEMENT

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Bridges are typically damaged/deteriorated due to various factors that require close evaluation to make informed decisions about repair/replacement. There are several aspects of study to evaluate bridges for repair/replacement, such as age, structural adequacy, and frequent usage. Further, bridges which are in poor condition must be identified to mitigate their damage/deterioration and as a result, maintain a safe environment for users. Therefore, to assess the need for funding, state Departments of Transportation are required to evaluate bridges by considering several factors, while prioritizing safety. In Texas, the Highway Bridge Program is responsible for funding bridges which are listed for repair/replacement. This is typically decided through their sufficiency rating system. However, the existing sufficiency rating method utilizes a complex formula which lacks some key details. This method can be improved by incorporating additional factors that could potentially result in a better and more efficient methodology. Consequently, the purpose of this study is to develop a decision tool for bridge repair/replacement, that incorporates factors such as condition, cost, risk, ease of repair/replacement, age, importance, public use, and geometry. Some factors contain sub-elements which were evaluated and weighted according to importance. To pursue this, methods such as regression analysis, decision matrices and the analytic hierarchy process were used. The decision tool will be executed on an interactive Excel-based platform. Excel Visual Basic macro functions will be used to create a user-friendly platform. The proposed tool shall be useful in making objective and data-driven decisions for local bridge maintenance, rehabilitation, and replacement.

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CHAPTER 1

Introduction

1.1 General

Transportation is the backbone of any successful society and bridges play a salient role in maintaining an effective transportation system. The transportation system has been significantly enhanced with the implementation of bridges, which have consequently resulted in a more efficient method of travel. Like any other structure constantly in use, bridges also deteriorate and require proper maintenance to ensure a safe environment for the public.

State departments of transportation (DOTs) and other bridge owners are typically faced with significant challenges in addressing the nation's highway bridge preservation and replacement needs. The U.S. bridge inventory consists of roughly 617,000 bridges, and more than 7.6% of the bridges are classified as structurally deficient (ASCE, 2021). Additionally, over 42% of existing bridges are over 50 years old and need various levels of repairs, rehabilitation, or replacement. Moreover, increasing travel demands, limited funding, and increasing costs of labor and materials could potentially yield challenges for bridge prioritization (ASCE, 2021).

Bridge prioritization for repair/replacement is directly linked to structural safety and functionality, consequently impacting public safety. Thus, factors such as bridge structural adequacy, serviceability, and the impacts on public use must be evaluated to determine whether they should remain in service or be replaced. Consequently, the Texas Department of Transportation (TxDOT) has been constantly investigating new bridge prioritization techniques.

The TxDOT bridge inventory includes more than 55,000 bridges open to public traffic, significantly more than any other U.S. state. Even with a significant number of bridges being newly constructed or replaced each year, slightly more than half of the bridge inventory is 40 years old of age or older (TxDOT, 2020). However, bridge data portrays that although Texas has some of the oldest bridges, in general, they have the some of the lowest numbers in poor condition as shown in Figure 1-1. Although bridge age seems to have minimal effect on the physical condition of the bridges, there are several other factors which should be taken into consideration when prioritizing bridges for repair or replacement.

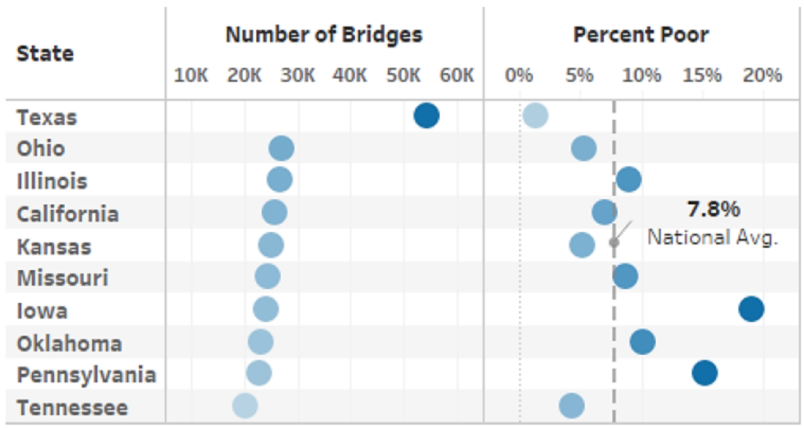


Figure 1-1: 2020 Report on Texas Bridges (TxDOT, 2020)

In the state of Texas, the Highway Bridge Program (HBP) is responsible for selecting bridges that require either rehabilitation or replacement (TxDOT, 2019). Rehabilitation or replacement decisions are typically decided through their sufficiency rating, which considers various factors. However, the existing sufficiency rating method lacks some key details, and can be improved by incorporating additional factors that could potentially result in a better and more efficient rating methodology. Further, to facilitate a more robust bridge priority rating (PR) system, more in-depth evaluations should be made on bridges by considering the condition of each individual element. Therefore, as of 2014, it is a requirement that all states collect element-level inspection data (ELID) for all bridges on the National Highway System (NHS). The NHS consists of roadways important to the nation’s economy, defense, and mobility (FHWA, 2012).

ELID are collected by the state of Texas; however, they are not being used for the bridge prioritization process. The current study developed PR scores for the bridges through expansion of the sufficiency rating system (SRS), incorporating additional information such as ELID, to make a more accurate assessment on the status of bridges. The proposed tool shall be useful in making objective and data-driven decisions for local bridge maintenance, rehabilitation, and replacement. This new and improved tool could be reviewed and applied nation-wide and will be beneficial to the transportation industry.

1.2 Background

1.2.1 Sufficiency Rating

The SRS is a bridge evaluation method developed by the Federal Highway Administration (FHWA), which indicates the sufficiency of a bridge to remain in service (FHWA, 1995). The SRS ranges on a scale of 0 to 100, where 100 indicates an entirely sufficient bridge, and zero, an entirely deficient bridge. The SRS consists of four main factors: namely, structural adequacy and safety (S1), serviceability and functional obsolescence (S2), essentiality for public use (S3), and special reduction (S4) (TxDOT, 2019). The weights of these factors are 55, 30, 15, and 13, respectively. Further, each of these factors contain various subfactors which ultimately determine the final sufficiency rating score. After a sufficiency rating score has been determined for each bridge, repair/replacement decisions are made based on various thresholds. For example, TxDOT (2019) uses thresholds as shown in Table 1-1 for bridge decision making. The SR for a given bridge is the sum of S1, S2, and S3 minus S4, when applicable. A flowchart showing the bridge eligibility for HBP funding is shown in Figure 1-2.

Table 1-1: TxDOT Bridge Eligibility for Repair/Replacement (TxDOT, 2019)

Bridge Classification	Sufficiency Rating	Eligibility for HBP Funding
Not Deficient	81 - 100	Not Eligible for Repair/Replacement
Deficient	50 – 80	Eligible for Repair
Deficient	0 - 49	Eligible for Replacement

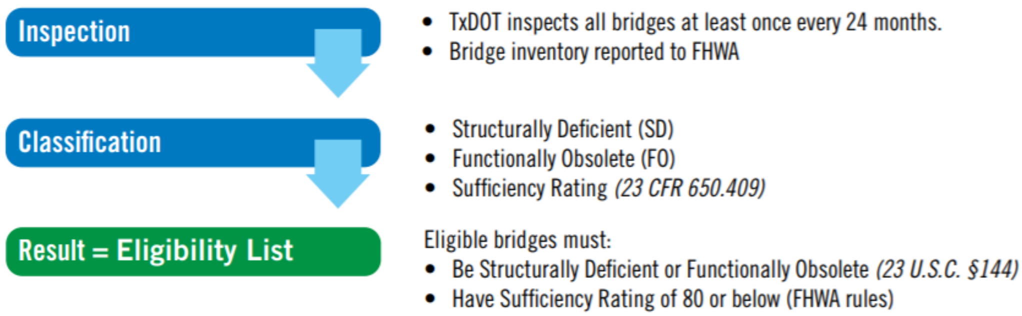


Figure 1-2: Bridge Eligibility Process for Repair/Replacement (TxDOT, 2019)

1.2.2 Bridge Programming and funding

Previously, to determine which bridges should be repaired or replaced, federal administration required states to provide a list of eligible bridges on the NHS. The HBP was the federal-aid program which provided funding to all states for bridge repair/replacement projects. Table 1-1 also portrays the eligibility for HBP funding (TxDOT, 2019). Moreover, the SRS was the requirement of the HBP for determination of which bridges should be programmed for repair/replacement. However, in 2012, President Obama signed the Moving Ahead with Progress in the 21st Century Act (MAP-21), for fiscal years 2013 and 2014. The MAP-21 Act reconstructed the federal-aid programs and therefore, discontinued the HBP (FHWA, 2012). Although Texas maintained the HBP as a state program, they are also seeking better methods to prioritize the bridges. The HBP and two other federal aid programs were merged into the National Highway Performance Program (NHPP) as shown in Figure 1-3.

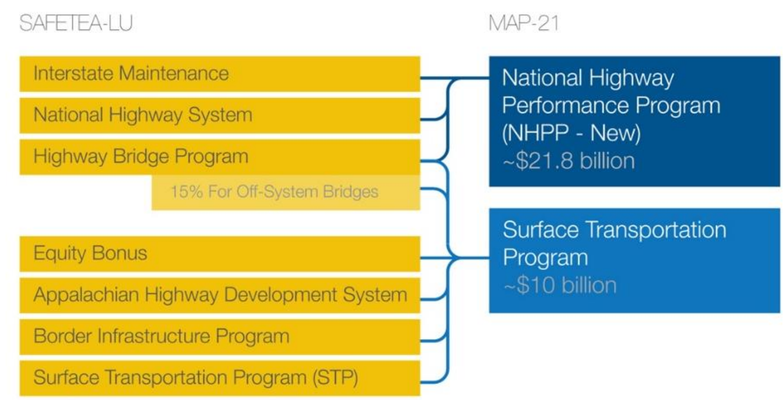


Figure 1-3: MAP-21 Program Consolidation (Transportation for America, n.d.)

MAP-21 also established classifying bridges using the Good, Fair, and Poor system (FHWA, 2021). If the lowest National Bridge Inventory (NBI) condition rating for Item 58 (Deck), Item 59 (Superstructure), Item 60 (Substructure), or Item 62 (Culvert) is greater than or equal to 7, the bridge is classified as Good; if it is less than or equal to 4, the classification is Poor. Bridges rated 5 or 6 are classified as Fair (FHWA, 2021). Additionally, under MAP-21, each state was required to prepare a Transportation Asset Management Plan (TAMP) for bridges on the NHS to improve or preserve the asset condition and the performance of the system (FHWA, 2019). MAP-21 defined asset management as "a strategic and systematic process of operating, maintaining, and improving physical assets, with a focus on engineering and economic analysis based upon quality information, to identify a structured sequence of maintenance, preservation, repair, rehabilitation, and replacement actions that will achieve and sustain a desired state of good repair over the lifecycle of the assets at minimum practicable cost" (23 U.S.C. 101(a)(2), MAP-21 § 1103). Consequently, each state submitted the TAMPs which aimed to incorporate the risk and performance-based requirements of MAP-21. Map-21 was followed by the Fixing America's Surface Transportation Act (FAST Act), which built on MAP-21. The FAST Act maintained focus on safety and structure of various highway-related programs and continued efforts to streamline project delivery (ADOT, 2016). Additionally, as part of the FAST Act, congress authorized non-National Highway System bridges on Federal-aid highways to be funded with NHPP funding. The FAST Act was authorized for fiscal years 2016 to 2020.

In 2021, the President's budget request included $810 billion for a 10-year surface transportation reauthorization proposal to run from fiscal year 2021 through 2030. The new proposal will build upon the success of the FAST Act (FHWA, 2021). Therefore, the future plans of the government are centered around the same risk and performance-based theme as MAP-21 and the FAST Act. Consequently, it is imperative to develop new methods of assessing the physical condition of bridges and the public of bridge repair/replacement activities.

1.2.3 Element-level Inspection Data

Modern bridge management practices utilize detailed bridge inspection processes to meet the growing demands of the transportation industry. Some of these include the introduction of ELID, deterioration modeling and life-cycle planning. MAP-21 required states to collect and submit ELID for all NHS bridges, in addition to the NBI condition rating data (FHWA, 2012). All states were required to begin element-level inspections in 2014 (Campbell et al., 2016). The new federal laws prompted new requirements such as funding re-allocations of government agencies, and additional data collection requirements for states to maintain this funding (FHWA, 2012). Campbell et al. (2016) investigated the collection of ELID in 14 states and found that the majority collected the data even before MAP-21 was initiated, though their methods of utilizing it varied. Although the federal laws require states to collect ELID, they gave no further direction on how to utilize it and incorporate it in bridge decision making for repair/replacement. Therefore, it is the responsibility of the state DOTs to find the most optimum methods to use the data. Consequently, states such as Virginia and Connecticut have developed bridge decision tools in the form of priority ranking formulas (VDOT, 2018; CTDOT, 2019).

1.2.4 Bridge Health Indices

The California Department of Transportation (CALTRANS) developed the Bridge Health Index (BHI), which is a single-number measure of the structural performance of a bridge or a network of bridges. The CALTRANS BHI is calculated by the ratio between the current element value (CEV) and the total element value (TEV) of bridge components, resulting in the remaining service life of the bridge. It is also useful for comparing structural health and providing resource allocation for a bridge database. This is done by using ELID and the failure cost of each element. However, incorporating the failure cost of an element can be challenging, since the true cost of an element's failure is unknown. Conversely, the BHI includes several useful concepts such as the weighting factor (WF) (Chase et al., 2016).

1.3 Problem Statement

The ability of a bridge to remain to service is directly linked to its structural safety and functionality, consequently impacting public safety. Therefore, factors such as bridge condition, geometry, public use, age, damage/deterioration risks, cost and ease of repair/replacement must be evaluated to determine whether they should remain in service or be replaced. Further, bridge condition should be evaluated in detail at the element level, to make more informed decisions about repair/replacement based on bridge elemental conditions. However, the existing sufficiency rating method, which is used to prioritize bridges, lacks some of these key details, and needs to be improved by incorporating additional factors (TxDOT, 2019). The current study shall develop bridge PR scores through expansion and re-evaluation of the existing sufficiency rating system.

The new tool is EXCEL-based and will provide automated calculations of PR scores, along with options for bridge repair/replacement.

1.4 Research Objectives

1. To develop a new decision tool which will be useful in making objective and data-driven decisions for local bridge maintenance, rehabilitation, and replacement.
2. To propose and implement new factors for bridge repair/replacement prioritization decisions.
3. To examine the existing SRS and identify additional factors to implement into the tool.
4. To utilize bridge data provided by TxDOT and conduct data analysis to validate the new decision tool.
5. To assign and adjust appropriate weights to each proposed factor.
6. To develop a robust algorithm on MS EXCEL to determine the priority rating scores.
7. To utilize bridge elemental data to quantify the extent of damage.
8. To provide priority rankings and repair/replacement options for each bridge in the bridge inventory.

Chapter 2

Literature Review

2.1 National Bridge Inventory

The FHWA (1995) defines a bridge as "a structure including supports erected over a depression or an obstruction, such as water, highway, or railway, and having a track or passageway for carrying traffic or other moving loads, and having an opening measured along the center of the roadway of more than 20 feet between undercopings of abutments or spring lines of arches, or extreme ends of openings for multiple boxes; it may also include multiple pipes, where the clear distance between openings is less than half of the smaller contiguous opening" (viii). All structures identified as bridges are stored in a database called the NBI, which contains the aggregation of structure inventory and appraisal data. Additionally, NBI data must fulfill the requirements of the National Bridge Inspection Standards (NBIS). The NBIS refer to Federal regulations establishing requirements for inspection procedures, frequency of inspections, qualifications of personnel, inspection reports, and preparation and maintenance of a state bridge inventory. The NBIS apply to all structures defined as bridges located on all public roads (FHWA, 1995). Each bridge, whether on-system or off-system is identified by its 15-digit NBI number. On-system bridges are owned and maintained by the state on the TxDOT designated Highway System. Contrarily, off-system bridges are owned by a county, city or other local or regional governmental unit. For on-system bridges, the NBI number consists of a two-digit district number, a three-digit county number, a zero, a four-digit control number, a two-digit section number, and the three-digit permanent structure number (TxDOT, 2018). Additionally, the NBI number for off-system bridges, consists of the same structure as on-system bridges, except the last three digits of the off-system bridges are the unique bridge number.

2.2 Bridge Priority Ratings Across the U.S.

2.2.1 General

There are several factors which have influenced the development of bridge prioritization software and requirements throughout the U.S. Some of these factors include requirements from federal organizations, availability of data, and software available to assist in the bridge prioritization process. As previously discussed in section 1.2.2, the HBP was responsible for funding bridges which were prioritized for repair or replacement based on the sufficiency rating. As per the requirements of the HBP, the bridges with lowest sufficiency rating and functionally obsolete bridges were programmed as most in need of prioritization. Currently, due to MAP-21, the FAST act, and the discontinuity of the HBP, states are developing their own methods of prioritizing bridges in accordance with the new federal requirements. As a requirement of the FAST Act, states need to develop a risk and performance-based asset management plan for the NHS to improve or preserve asset condition and system performance. Therefore, states have developed their own methods of ranking centered around the goals of MAP-21 and the FAST Act. However, since the FHWA did not provide a universal method of prioritizing bridges, states have developed state-specific formulas and methods of bridge prioritization. Priority ratings have only been developed for a small number of states to date, and this might be due to the lack of availability of bridge inspection data required to develop a robust priority tool, availability of data; but no means of using the data, or lack of resources to develop a priority tool. Consequently, for some states, instead of using priority tools which are usually inclusive of several factors apart from bridge condition, they use evaluation tools such as the bridge health index, bridge condition index and similar criterion which are solely based on the condition of the bridge. This method excludes factors such as bridge geometry, public impacts, and cost. Although bridge condition has shown to be the most impactful criteria of bridge prioritization, it is not the only criteria for decision making (VDOT, 2018; ADOT 2016). Therefore, bridge priority tools/formulas have been developed by the following states/agencies.

2.2.2 AASHTO BrM Bridge Management System

AASHTOWare Bridge Management System (BrM) (2021) is a bridge management software that assists engineers and decision-makers in the selection and timing of preservation, rehabilitation, and replacement projects for their structures. BrM was first developed under a National Cooperative Highway Research Program (NCHRP) project sponsored by the FHWA in the early 1990s and shortly after was transferred to AASHTO for further development, maintenance, and support (AASHTO, n.d.). Continuous improvements were being made to BrM to support asset management needs (AASHTO, 2020). BrM provides a data-driven approach to select projects and meet the specific needs, policies, and practices of the agency as they relate to their Transportation Asset Management Plan (TAMP). Features of BrM include the utility tree, deterioration rates, benefits, and actions performed, funding, and performance measures (AASHTO, 2018). Figure 2-1 shows the states that licensed BrM in FY2020.

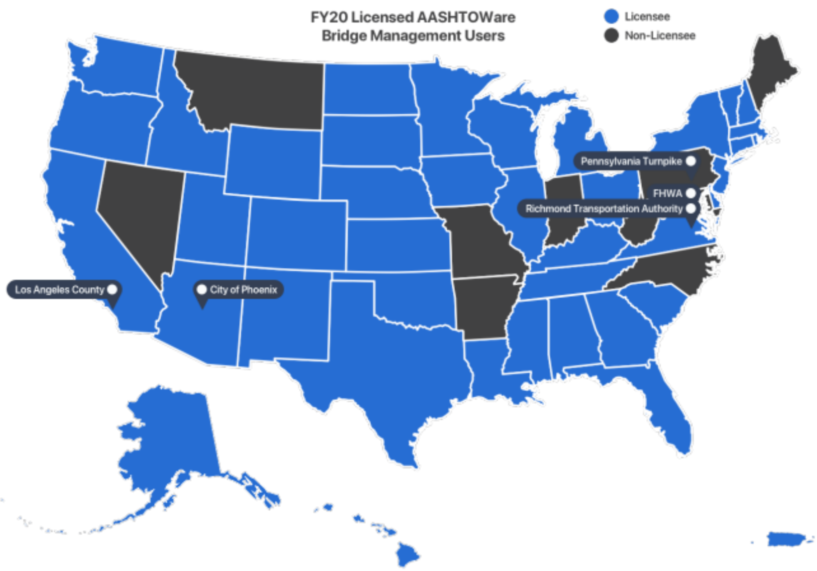


Figure 2-1: Licensed AASHTOWare BrM Users (AASHTO, 2020)

2.2.3 Virginia

The Virginia Department of Transportation (VDOT) (2018) developed a bridge priority scoring tool which ranked bridges according to five factors: importance, condition, design redundancy, structure capacity, and cost effectiveness. VDOT's State of Good Repair Program priority scoring tool uses the index method to evaluate each score on a 0-1 scale; where 0 represents lowest priority and 1 represents highest priority. Additionally, VDOT assigned weights to each factor based on recommendations from an expert panel of Professional Engineers. The importance and weight restriction factors were investigated in further detail by regression analysis. The structure of the VDOT priority tool is shown in Figure 2-2.

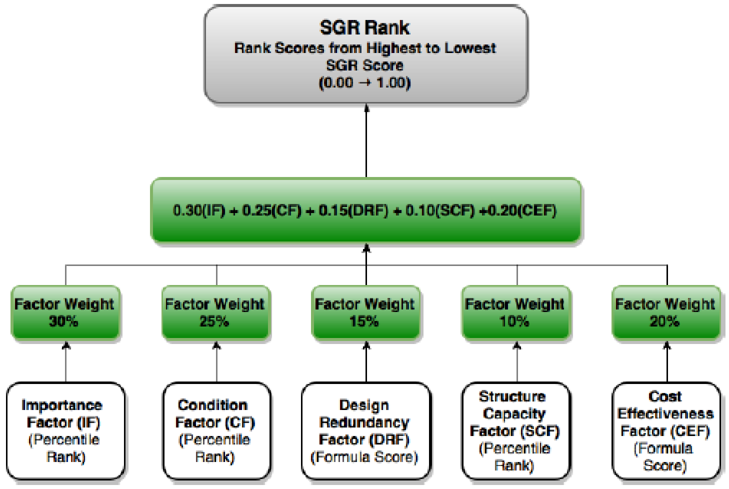


Figure 2-2: VDOT Priority Rating Score (VDOT, 2018)

2.2.2.1 Importance Factor for Virginia's Roadway Network

The Virginia Transportation Research Council (2016) developed a structure scoring tool that would rank the relative importance of VDOT-maintained structures to the highway network and economy of Virginia. The tool aimed to estimate the relative importance of a structure to the road system and to users by means of structure inventory items pertaining to the structure's use and location. A structure's relative importance ranking is determined by the explanatory variables selected by the expert panel, and the weight assigned to each explanatory variable by the expert panel. The importance ranking (IF score) encompassed nine explanatory variables: Total Average Daily Traffic per Lane, Average Daily Truck Traffic per Lane, Annualized Growth Rate of ADT, Bypass Impact, Access Impact, Base Highway Network, Strategic Highway Designation, Designated National Network, and Virginia Highway System. Each variable was normalized on a scale of 0-1 and were given weights according to recommendations from a panel of expert engineers. An Excel spreadsheet tool was created to perform the algebra to transform the selected inventory items into the explanatory variables and index values that determine a structure's IF score.

2.2.3 Connecticut

The Connecticut Department of Transportation (CTDOT) (2019) developed a bridge priority ranking tool based on the sufficiency rating. The PR represents the physical condition of the structure, with additional weight given to the ratings of the main structural components and the structure's load carrying capacity (CTDOT, 2019). The PR tool developed by CTDOT uses the sufficiency rating as the base and subtracts the effects of the deck, superstructure, substructure, or culverts, and inventory rating. The formula is designed in a manner by which the lowest PRs depict the highest priority for funding. The formulas established are dependent on whether the structure is a bridge or a culvert. The formulas are shown in Equations 1 and 2.

$$\text{Priority Rating (Bridge)} = SR - 2\left[1-\left(\frac{DC+SUB+SUP}{27}\right)\right] - 4\left[1-\frac{IR}{36}\right] \quad (1)$$

$$\text{Priority Rating (Culvert)} = SR - 2\left[1-\frac{CUL}{9}\right] - 4\left[1-\frac{IR}{36}\right] \quad (2)$$

Where:

SR = Sufficiency Rating

DC = Deck condition rating

SUB = Substructure condition rating

SUP = Superstructure condition rating

CUL = Culvert condition rating

IR = Inventory Rating (tons)

It is observed from the formula that the effect of the inventory rating was compared to the maximum value (in tons) of the HS-20 truck, which is 36 tons. However, this value was evaluated linearly; as the inventory rating decreases, the score increases. A value of 4 is also assigned to the inventory rating as compared to 2 for the deck, superstructure, and substructure. This implies a higher impact of the inventory rating on the PR.

2.2.4 Vermont

The Vermont Agency of Transportation (VTrans) (2006) developed a quantitative project prioritization method that assigns numeric scores to competing projects. The priority scores aim to guide stakeholders to classify projects that should be postponed and projects that should be accelerated. The priority tool includes eight factors of various points. The descriptions of the factors and points assigned are shown in Table 2-1. In Table 2-1 bridge condition is given the highest value of points (30) and this factor is weighted based on condition of major inspected components (deck, superstructure, substructure, and culvert). To obtain the final priority score, assigned points are summed together to yield a maximum value of 100.

Table 2-1: Vermont Bridge Priority Rating (VTrans, 2006)

Factor	Description	Points
Bridge Condition	Weighted based on condition of major inspected components (deck, superstructure, substructure, and culvert); more points assessed for higher levels of deterioration. The condition is determined at the most recent inspection.	30
Remaining Life	Correlates the accelerated decline in remaining life to condition.	10
Functionality	Compares roadway alignment and existing structure width, based on roadway classification, to accepted state standards. Too narrow or poorly aligned bridges are safety hazards and can impede traffic flow.	5
Load Capacity and Use	Is the structure posted or restricted? What is the inconvenience to the traveling public if the bridge is out of service? What is the average traffic use on the structure?	15
Waterway Adequacy and Scour Susceptibility	Are there known scour issues or concerns? Is the structure restricting the natural channel? Are channel banks well protected or vegetated?	10
Project Momentum	Points are assigned if the project has a clear right of way, has all environmental permits, and the design is ready and waiting for funds to become available.	5
Regional Input and Priority	Does the regional planning commission support the project from a local land-use and economic-development perceptive?	15
Asset – Benefit Cost Factor	This compares the benefit of keeping a bridge in service to the cost of construction. The “benefit” considers the traveling public by examining the traffic volume and the length of a detour if the bridge were posted. For example, a bridge with a high traffic count that does not have a good detour around it would get a higher benefit score.	10

2.2.5 Oregon

The Oregon DOT (ODOT) (2019) developed a bridge priority selection policy to replace or rehabilitate structurally deficient and functionally obsolete bridges through the HBP. HBP funding was allocated in several categories namely, all state bridges, large bridges (greater than

30,000 SF), small bridges (less than 30,000 SF), on-system bridges (functionally classified *major collector or greater*), and off-system bridges (functionally classified *minor collector or less*). Equation 3 was used to calculate the priority scores for small bridges, and Equation 4 shows the weight of each factor depicting maximum priority points, which is 105. To make appropriate decisions, additional information should be included in the application for rehabilitation or replacement. For example, if rehabilitation of the bridge is proposed instead of replacement, an estimate of the extended life of the bridge and an analysis showing the sufficiency rating of the bridge after the project has been completed should be provided. Upon receipt of the local agency applications, ODOT will review all application information for accuracy, then calculate the technical ranking priority points for the small bridges. Obtaining a higher priority score depicts a greater need for funding.

$$\text{Priority Points} = (SRF + TBF + LDF + UBF) \times 0.5 \times BNM \times FCM \tag{3}$$

$$\text{Max. Priority Points} = (50+5+25+25) \times 0.5 \times 1.414 \times 1.414 = 105 \text{ points} \tag{4}$$

Where:

SRF = NBIS Sufficiency Factor = (50 – Sufficiency Rating) [Max. 50 points]

TBF = Timber Deficiency Factor [Maximum 5 points]

LDF = Load Deficiency Factor [Maximum 25 points]

UBF = Use Benefit Factor [Maximum 25 points]

BNM = Bonus Need Multiplier [Maximum 1.414]

FCM = Functional Classification Multiplier [Maximum 1.414]

2.2.6 Iowa

The Iowa DOT (2020) developed bridge priority scoring formulas for county and city bridges. The formulas of the county and city bridges sum up to a maximum of 100 and 40 points, respectively. The factors and maximum points considered in the city bridge priority formula include sufficiency rating (10), estimated ADT (10), bypass detour length (10), and bridge posting (10). Also, the county bridge priority formula includes all the factors from the city formula as well as bridge width, bridge length, and cost/vehicle ratio. However, the weights of the factors in the county formula are redistributed, totaling 100 points. In this model, the priority points increase according to less favorable conditions. For example, the lower the sufficiency rating, the higher the points assigned to the priority score.

2.2.7 Arizona

The Arizona Department of Transportation (ADOT) (2016) developed a Bridge Rehabilitation and Replacement Subprogram which consists of two subcomponents: Bridge Fund for On-System (BRON) and Bridge Fund for Off System (BROS). This subprogram will be used until BrM is fully functional with updated inspection data, and new deterioration model and cost related data. Equations 5 and 6 will be used to aid in the prioritization and funding for eligible projects. ADOT utilizes two formulas: one for bridges and the other for culverts. There are 20 NBI items which are considered for bridges and 15 for culverts. The weighting factors shown in the equations are linearly scaled from 0.25 to 1.00. The NBI items will be scored using this scale and the maximum score for each factor is one. The items are shown beneath each equation.

$$\text{Bridge Priority Ranking} = \sum_{i=1}^{i=20}(NBI_i) * Weighting\ Factor_i \qquad (5)$$

N29, N109, N41, N19, Deficiency Classification, S.R., N58, N59, N60, N27, N64, N26, N51, N92A, N113, N53/N54, N55/N56, N71, N72, Elevation

$$\text{Culvert Priority Ranking} = \sum_{i=1}^{i=15} (NBI_i) * Weighting\ Factor_i \qquad (6)$$

N29, N109, N41, N19, Deficiency Classification, S.R., N62, N27, N64, N26, N51, N113, N71, N72, Elevation

2.2.8 Summary of Bridge Priority Ranking Systems

Several states throughout the US have developed in-house methods of prioritizing bridges for rehabilitation or replacement. All of the priority ranking systems which were studied emphasized on the main components of the bridge (deck, superstructure, and substructure) or culverts by adding more weight to them compared to other factors. Additionally, various other factors were considered, such as bridge geometric features, traffic, and load capacity. However, none of the studied ranking systems developed new methods of incorporating ELID or considered an Ease of Repair or Replacement (EROR) factor. The current study also incorporated new concepts like the bridge severity index (SI) which utilizes elemental data to provide more detailed descriptions of the bridge condition.

CHAPTER 3

Methodology

To facilitate the development of the bridge decision tool, a series of tasks needed to be completed. First, the existing SRS from the Texas Department of Transportation (TxDOT) was reviewed, and aspects of this system was identified for improvement by incorporating additional information as feasible. Secondly, appropriate data, such as the NBI condition rating, NBEs, and cost data were collected. The TxDOT GIS Open Data Portal and the TxDOT bridge inspection database, AssetWise were the primary data sources used. Upon obtaining all required data, eight factors were developed to formulate the bridge decision tool for repair or replacement. Weights were proposed for each factor using two methods, namely, the Analytic Hierarchy Process (AHP) and expert opinion surveys from Engineers at TxDOT. Using the newly developed formula, priority rating scores were assigned to all on-system bridges in the TxDOT bridge inventory.

After the new formula was developed and the priority scores were assigned to the bridge inventory, the tool was tested on a sample of 25 bridges. Upon achieving good results, heat graphs were incorporated into the tool to assist with repair/replace decisions. A flowchart is shown in Figure 3-1 for the complete methodology.

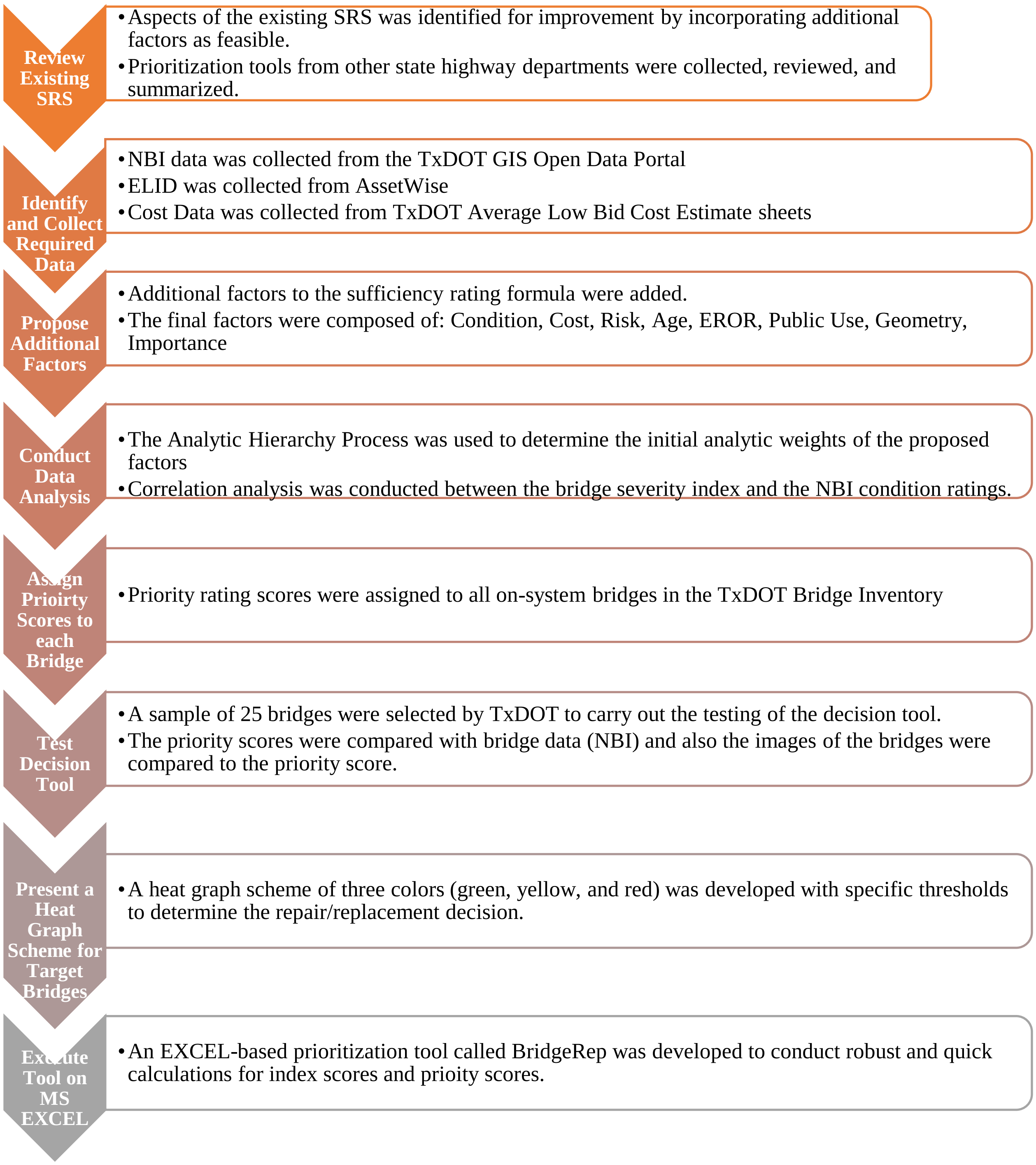


Figure 3-1: - Methodology

CHAPTER 4

Results

4.1 Review of the Existing SRS

The existing SRS was reviewed, and a comparison was made between the FHWA SRS and the TxDOT SRS (FHWA, 1995; TxDOT, 2019). The similarities and differences are listed in Table 4-1. The table depicts that the TxDOT formula and FHWA formula are the same for the general formula, and individual factors (S_1, S_2, S_3). The two formulas also have the same maximum and minimum values (0-100). However, there is a difference in the limit for the rating reduction; the FHWA formula has a limit of 13% and TxDOT has a limit of 15%. Figure 4-1 shows the FHWA detour length reduction criteria. Additionally, another difference exists in the special reduction limit. For TxDOT, the special reduction factor is only used when the factors S_1 through S_3 are greater than or equal to 50. Contrarily, the special reduction factor for the FHWA is a fixed value in the formula and limited to 13%. The formulas for the FHWA SRS and TxDOT SRS are shown in Appendix C.

A statewide study was conducted on the SRS and the results are depicted in Figure 4-2. It is observed that the majority of the states (66%) used the FHWA SRS formula for funding eligibility.

Table 4-1: Comparison Between FHWA and TxDOT Sufficiency Rating System (TxDOT, 2019; FHWA, 1995)

Factor	**TxDOT**	**FHWA**
General formula ($S_1+S_2+S_3-S_4$)	✔	✔
Structural adequacy and safety(S_1)	✔	✔
Serviceability and functional obsolescence (S_2)	✔	✔
Maximum (100) and minimum (0) limit	✔	✔
Rating Reduction limit	15%	13%
Special Reduction factor limit	S_4 is a Special Reduction used only when $S1 + S2 + S3 \geq 50$	13%

✔ - Depicts that the factor for TxDOT and FHWA are the same.

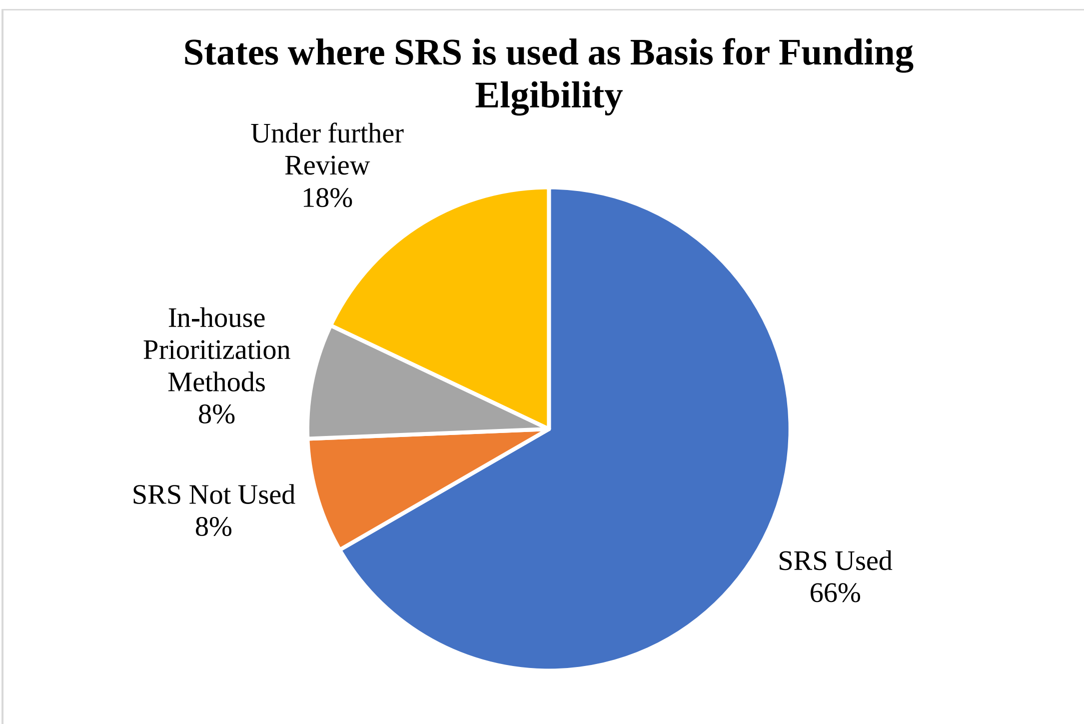


Figure 4-2: FHWA Sufficiency Rating System Used for Funding Eligibility

4.2 Collection of Required Data

The latest ELID from the National Bridge Elements (NBE) were obtained through the TxDOT bridge inventory. ELID will particularly be incorporated into the tool as they provide information about the extent of damage/deterioration that a particular bridge has undergone. These ELID are represented by dividing the total quantities of the element into the condition states as shown in Table 4-7. Table 4-6 shows an example of the material defects for reinforced concrete. The AASHTO Manual for Bridge Element Inspection (2019) provided a thorough categorization of the elements. The respective groups of data included, deck, superstructure, substructure, and culverts as shown in Tables 4-2 – 4-5. The tables portray the NBEs in terms of material types, units and element numbers which were considered for the study. Figure 4-3 depicts a visual perspective of localized spalling in a concrete beam (NJDOT, 2015).

Additional data, such as scour-related reports/documents, bridge structural condition history sheets and current load ratings were also used to assist in this process. Moreover, cost data were taken from the TxDOT Average low bid cost estimates as shown in Table 4-9. Also, Table 4-8 shows data from the TxDOT GIS Open Data Portal.

Table 4-2: Deck (AASHTO, 2019)

Element	Units	Decks (Element #)	Slab (Element #)
Reinforced concrete Deck/Slab	ft^2	12	38
Prestressed Concrete Deck	ft^2	13	
Prestressed Concrete Top Flange	ft^2	15	
Reinforced Concrete Top Flange	ft^2	16	
Steel Deck – Open Grid	ft^2	28	
Steel Deck – Concrete Filled Grid	ft^2	29	
Steel Deck – Corrugated/Orthotropic/Etc.	ft^2	30	
Timber Deck/Slab	ft^2	31	54
Other Material Deck/Slab	ft^2	60	65

Table 4-3: Superstructure (AASHTO, 2019)

Element	Units	Steel	Prestressed Concrete	Reinforced Concrete	Timber	Masonry	Other
Girder/Beam	ft	107	109	110	111		112
Closed Web/Box Girder	ft	102	104	105			106
Stringer	ft	113	115	116	117		118
Truss	ft	120			135		136
Arch	ft	141	143	144	146	145	142
Floor Beam	ft	152	154	154	156		157
Cable - Primary	ft	147					
Cable - Secondary	each	148					149
Gusset Plate	each	162					
Pin, Pin and Hanger Assembly, or Both	each	161					

Table 4-4: Substructure (AASHTO, 2019)

Element	Units	Steel	Prestressed Concrete	Reinforced Concrete	Timber	Masonry	Other
Columns	each	202	204	205	206		203
Column Tower (Trestle)	ft	207			208		
Pier Wall	ft			210	212	213	211
Abutment	ft	219		215	216	217	218
Pile	each	225	226	227	228		229
Pier Cap	ft	231	233	234	235		236
Pile Cap/Footing	ft			220			

Table 4-5: Culverts (AASHTO, 2019)

Element	Units	Steel	Prestressed Concrete	Reinforced Concrete	Timber	Masonry	Other
Culvert	ft	240	245	241	242	244	243

Table 4-6: Material Defects (IDOT, 2015)

Reinforced Concrete - Condition State Definitions				
Defect	**CS 1 - Good**	**CS 2 - Fair**	**CS 3 - Poor**	**CS 4 - Severe**
Delamination / Spall / Patched Area (1080)	None.	Delaminated. Spall 1 in. or less deep or 6 in. or less in diameter. Patched area that is sound.	Spall greater than 1 in. deep or greater than 6 in. diameter. Patched area that is unsound or showing distress. Does not warrant structural review.	The condition warrants a structural review to determine the effect on strength or serviceability of the element or bridge; OR a structural review has been completed and the defects impact strength or serviceability of the element or bridge.
Exposed Rebar (1090)	None.	Present without measurable section loss.	Present with measurable section loss, but does not warrant structural review.	
Efflorescence / Rust Staining (1120)	None.	Surface white without build-up or leaching without rust staining.	Heavy build-up with rust staining.	
Cracking* (1130)	Insignificant cracks or moderate width cracks that have been sealed.	Unsealed moderate width cracks or unsealed moderate pattern (map) cracking.	Wide cracks or heavy pattern (map) cracking.	
Abrasion / Wear (1190)	No abrasion or wearing.	Abrasion or wearing has exposed coarse aggregate but the aggregate remains secure in the concrete.	Coarse aggregate is loose or has popped out of the concrete matrix due to abrasion or wear.	
Distortion (1900)	None.	Distortion not requiring mitigation or mitigated distortion.	Distortion that requires mitigation that has not been addressed but does not warrant structural review.	
Settlement (4000)	None.	Exists within tolerable limits or arrested with no observed structural distress.	Exceeds tolerable limits but does not warrant structural review.	
Scour (6000)	None.	Exists within tolerable limits or has been arrested with effective countermeasures.	Exceeds tolerable limits, but is less than the critical limits determined by scour evaluation and does not warrant structural review.	
Damage (7000)	Not applicable.	The element has impact damage. The specific damage caused by the impact has been captured in condition state 2 under the appropriate material defect entry.	The element has impact damage. The specific damage caused by the impact has been captured in condition state 3 under the appropriate material defect entry.	The element has impact damage. The specific damage caused by the impact has been captured in condition state 4 under the appropriate material defect entry.

(a) (b)

Figure 4-3: Typical Concrete Encasement Condition (Left), Localized Spalling of Concrete Encasement (Right) (NJDOT, 2015)

Table 4-7: Bridge Element Inspection Report (AssetWise, 2021)

Name	Env.	Total Quantity	Units	State 1	State 2	State 3	State 4	Details
241 - Reinforced Concrete Culvert	3 - Mod.	695	ft.	623	70	2	0	View
1080 - Delamination/Spall/Patched Area		2		0	0	2	0	View
1130 - Cracking (RC and Other)		70		0	70	0	0	View
8270 - 270-Wing Wall - Reinforced Concrete	3 - Mod.	4	each	0	4	0	0	View
1130 - Cracking (RC and Other)		4		0	4	0	0	View

Table 4-8: Bridge Data (TxDOT, 2021)

OBJECTID	Bridge ID	STATE_HWY_DEPT_DIST	CNTY_CD	CNTY_RD_ID	CITY_ST_NBR	INV_RTE_MPT	PERM_BRDG_NBR
1866	021200AA0226001	02	120	AA02	26	00.200	001
1867	021200AA0226002	02	120	AA02	26	02.400	002
1868	021200AA0226003	02	120	AA02	26	06.700	003
1869	021200AA0233001	02	120	AA02	33	00.300	001
1870	021200AA0240001	02	120	AA02	40	04.200	001
1871	021200AA0243001	02	120	AA02	43	01.000	001
1872	021200AA0243002	02	120	AA02	43	01.300	002
1873	021200AA0243004	02	120	AA02	43	03.200	004
1874	021200AA0243005	02	120	AA02	43	04.000	005
1875	021200AA0243007	02	120	AA02	43	10.580	007

Table 4-9: TxDOT Average Low Bid Cost Estimates (TxDOT, 2020)

MAINTENANCE PROJECT - AVERAGE LOW BID

District: ALL

UPDATED :: 09/15/2020

			STATEWIDE					DISTRICT NAME: DISTRICT NUMBER:
			3 Month			12 Month		
ITEM CODE	ITEM DESCRIPTION	ITEM UNIT	STATEWIDE 3M COUNT	STATEWIDE 3M QUANTITY	STATEWIDE 3M AVG	STATEWIDE 12M COUNT	STATEWIDE 12M QUANTITY	STATEWIDE 12M AVG
01006001	PREPARING ROW	AC				6	12.85	$5,872.37
01006002	PREPARING ROW	STA	4	31.00	$1,344.39	18	105.50	$2,719.68
01006003	PREPARING ROW(TREE)(5" TO 12" DIA)	EA				1	43.00	$400.00
01006006	PREP ROW (TREE)(LESS THAN 24" DIA)	EA				1	16.00	$500.00
01006009	PREPARING ROW (TREE) (6" TO 24" DIA)	EA				1	1.00	$1,500.00
01006016	PREPARING ROW (TREE) (36" TO 48" DIA)	EA				1	1.00	$2,500.00
01046001	REMOVING CONC (PAV)	SY				3	2,357.15	$15.04
01046002	REMOVING CONC (PAV)	CY				1	61.00	$100.00
01046009	REMOVING CONC (RIPRAP)	SY	7	1,315.00	$30.18	37	10,037.00	$36.85
01046010	REMOVING CONC (RIPRAP)	CY				7	336.00	$111.58
01046011	REMOVING CONC (MEDIANS)	SY	1	125.00	$25.00	3	280.00	$45.80

4.3 Determination of Average Factor Weights by the AHP

The AHP is a method which can be used to determine the objective weights of criteria in a process (Saaty, 1970). This process is shown in Figure 4-4. The figure depicts four levels; the first level illustrates the goal/objective which is to repair or replace a bridge, the second and third levels depict the criteria and sub-criteria, and the fourth level includes the alternatives which are chosen based on the decision made. The average weights of the main factors of the decision tool were preliminarily determined using the information gathered from Table 4-10 as a basis for determining the importance of each factor. A thorough literature review was carried out to determine the weights used for similar factors to those used in this current study.

Two approaches can be taken to find the criteria weights: subjective or objective. For the objective approach, criteria weights can be derived from available technical data and for the subjective approach, they can be derived from the decision maker's judgment (Suthanaya and Artamana, 2017). There are at least three levels used in the AHP process. The first level is the goal or objective, the second level contains multiple criteria that influence the goal, and the third level contains the alternatives. For this AHP process, the relative weightings between several alternatives were obtained based on the average weights gathered in the literature review which is shown in Table 4-10. To check the consistency of the pairwise matrix, the consistency index (CI) was calculated using Eq. 7. To determine the acceptance of the CI value, it must be checked against the Random Index (RI) as shown in Table 4-11. The RI is the average CI of a randomly generated reciprocal matrices (500 sample size) with dimension n. Based on the ratio of the CI to RI, the degree of inconsistency of the matrix, defined by the consistency ratio (CR) can be calculated. The value of CR $\leq$ 0.1 indicates that the matrix is accepted with sufficient consistency. However, a CR > 0.1 indicates that the inconsistency is too large and unacceptable, and therefore the decision makers must re-check their judgments (Suthanaya and Artamana, 2017).

The EROR factor was included in Table 4-10 with an estimated weight of 5% since it is a new factor. Using AHP, a pairwise matrix was created to determine the criteria weights as shown in Table 4-12. The matrix was developed by using the importance criteria in Table 4-13. Lastly, the final factor weights from the AHP process are shown in Table 4-14 (VTrans, n.d.; Yari, 2018; VDOT, 2018; KDOT, 2010; NYSDOT, 2018; Abu Dabous and Alkass, 2010; Mansour et. al, 2019).

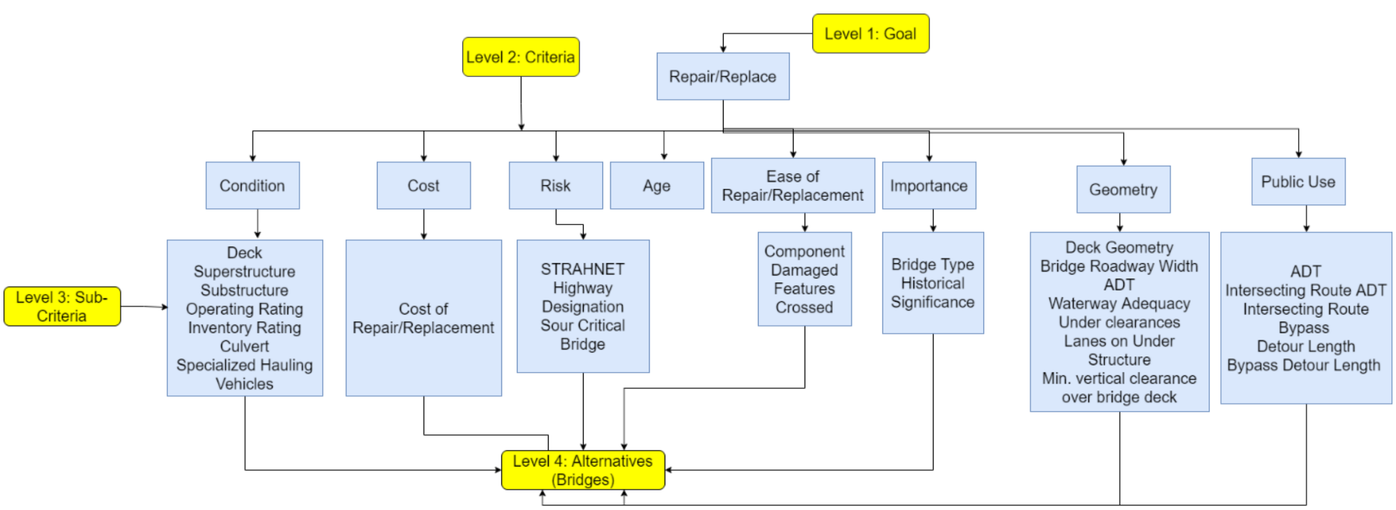


Figure 4-4: Decision Tool AHP

Table 4-10: Adjusted Approximate Weights

Factor	Vermont	New Hampshire	Virginia	Kansas	New York	Canada	Egypt	Sufficiency Rating	Adjusted Approximate Weights
Condition	40	40	30	74	47.5	51	63	55	40
Cost	10	-	20	-	-	-	-	-	10
Risk	-	15	10	-	20	9	-	15	10
Age	10	5	-	-	-	-	-	-	5
Historical Importance	-	-	-	-	-	-	3	-	5
Geometry	5	5	30	12.2	-	19		30	10
Public Use	15	-	-	-	27.5	-	-	15	15
EROR									5
Total									100

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (7)$$

Table 4-11: Random Consistency Index (Suthanaya and Artamana, 2017)

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0, 58	0, 9	1, 12	1, 24	1, 32	1, 41	1, 45	1, 49

Table 4-12: Analytic Hierarchy Process for Factor Weights

Factor	Condition	Geometry	Public use	Risk	Cost	Age	EROR	Importance	Eigenvector (ρi)	Wi	Xi	λmax
Condition	1	4	5	5	6	8	9	9	388800	5.00	0.39	3.57
Geometry	1/4	1	3	3	5	6	7	7	3308	2.75	0.22	1.90
Public use	1/5	1/3	1	1	4	5	6	6	48	1.62	0.13	1.09
Risk	1/5	1/3	1	1	4	5	6	6	48	1.62	0.13	1.09
Cost	1/6	1/5	1/4	1/4	1	3	4	4	0	0.75	0.06	0.52
Age	1/8	1/6	1/5	1/5	1/3	1	3	3	0	0.47	0.04	0.32
EROR	1/9	1/7	1/6	1/6	1/4	1/3	1	2	0	0.30	0.02	0.21
Importance	1/9	1/7	1/6	1/6	1/4	1/3	1/2	1	0	0.26	0.02	0.18
										12.78		8.86
											CI =	0.12
									CR =	0	<0.1	**OK**

Table 4-13: Importance Criteria for AHP (Suthanaya and Artamana, 2017)

Importance Criteria	
1	equal importance
3	moderate importance
5	strong importance
7	very strong importance
9	extreme importance
2, 4, 6, 8	intermediate values

Table 4-14: Analytic Factor Weights

Factor	**Weight**
Condition	0.39
Geometry	0.22
Public use	0.13
Risk	0.13
Cost	0.06
Age	0.04
EROR	0.02
Historical Importance	0.02

4.4 Additional Factors for New Decision Tool

A new rehabilitation or replacement decision tool for bridges was proposed via incorporating additional factors in the existing SRS as feasible, such as repair/maintenance history, existing condition at bridge element levels, repair or replacement cost, importance of the structure and age. This expanded tool will allow a more rational prioritization ranking of target bridges. Each factor will range on a scale of zero to 1. The final PR ranges on a scale of zero to 10; where 10 is most in need of prioritization. Equations 7 and 8 show the On and Off-system PR formulas. Equations 9 and 10 show that the coefficients (weights) of each formula, add up to 10. Figure 4-5 shows the breakdown of the On-System PR.

On-System PR = a*(C) + b*(CT) + c*(R) +d*(A) + f*(E) + g*(I) + h*(G) + k*(P) (7)

Off-System PR = m*(C) + n*(R) +p*(A) + r*(I) + s*(G) + t*(P) (8)

Weights for formula (1): a + b + c + d + f + g + h + k = 10 (9)

Weights for formula (2): m + n + p + r + s + t = 10 (10)

Where:

C = Condition

CT = Cost

R = Risk

A = Age

E = Ease of Repair/Replacement

I = Importance

G = Geometry

P = Public Use

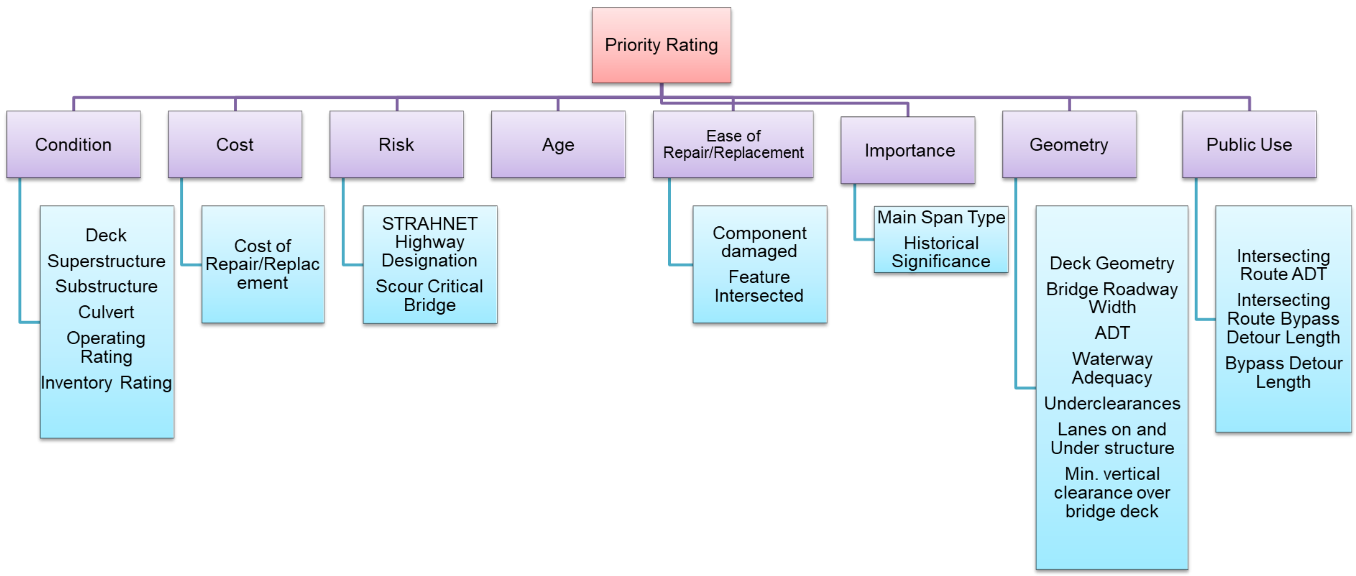


Figure 4-5: Decision Tool Factors and Sub-factors

4.4.1 Condition Factor

The condition factor measures the condition of the major components of the bridge (deck, superstructure, and substructure (DSS), culvert) and the capability of the bridge to carry required loads. Consequently, 50% of the condition factor describes the condition of the main bridge components and 50% describes the load restriction factor as shown in Eq. 11. The flowchart for the condition factor is shown in Figure 4-6.

The DSS or culvert score of the condition factor is calculated using two different formulas for On-system and Off-system bridges. For On-system bridges, the condition factor utilizes ELID to calculate the DSS/Culvert score as shown in Eq. 12. Therefore, 50% of the DSS/Culvert score is composed of elemental data and the other 50% is composed of NBI condition ratings of the DSS/Culvert. Figure 4-7 shows the correlation between the Bridge SI and NBI scores which has a correlation coefficient of 0.705, which indicates a strong correlation between the two variables.

Using the bridge elemental data, the bridge SI is calculated as shown in Eqs. 13 and 14. The SI formula incorporates the quantity of each element in its respective condition state and expresses its impact by considering the WF assigned. To normalize the severity scale, the product of the element quantity and the WF were compared to the total element quantity. To find the SI of the entire bridge, the importance of each bridge component needs to be considered. Therefore, a relative element weight scheme was obtained initially through the AHP, then confirmed by a panel of expert Engineers at TxDOT. The relative element weights (I_e) are shown in Table 4-15.

Contrarily, for off-system bridges, the entire DSS/Culvert score depends on only the NBI condition ratings as shown in Eqs. 15 and 16. ELID is typically not collected for most off-system bridges, therefore, the physical condition only depends on the NBI condition ratings.

For the load restriction factor (LRF), the HS-20 truck loadings were used to determine the rating factor thresholds as shown in Table 4-16. The rating factor was calculated for each bridge based on the HS-20 36 T maximum loading. The rating factor was calculated by dividing the Inventory and Operating Rating Gross Loading (tons) by the HS-20 loading of 36 T.

Specialized hauling vehicles (SHVs) and emergency vehicles (EVs) were also accounted for in the LRF factor, however the HS-20 truck loading is the default value, since the data for SHVs and EVs are limited. The criteria developed for incorporating SHVs and EVs are shown in Tables 4-17 and 4-18.

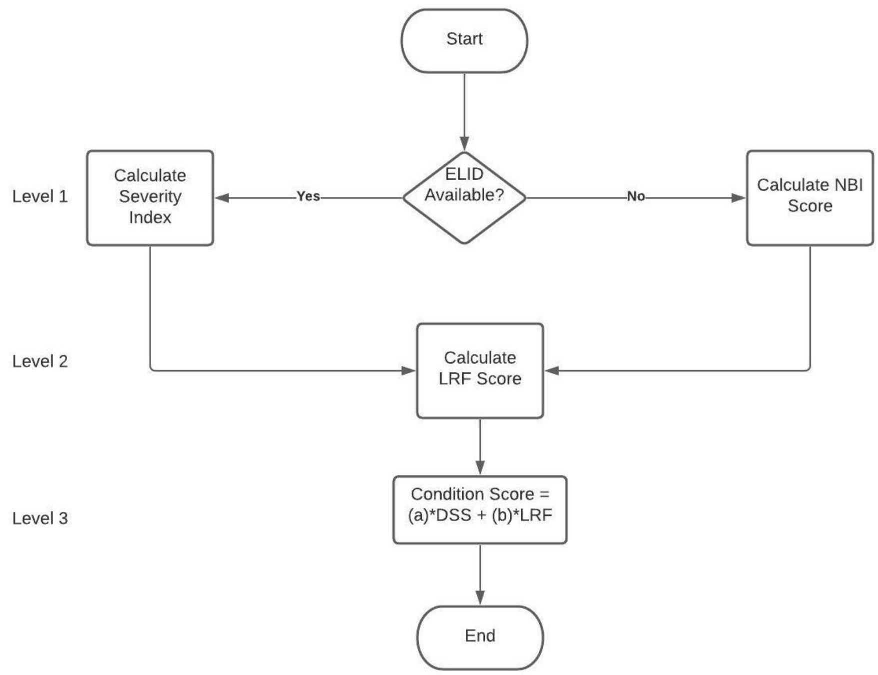


Figure 4-6: Condition Factor Flowchart

Condition Factor = 0.5*DSS/Culvert Score + 0.5*Load Restriction Factor (11)

DSS/Culvert Score = 0.5*NBI Score + 0.5* Bridge Severity Index (12)

$$SI_L = \frac{(\sum Q_i * WF_i)}{\sum Q_e} \tag{13}$$

$$SI_B = \frac{\sum SI_L * Ie}{\sum Ie} \tag{14}$$

$$\text{NBI Score} = \left(1 - \frac{Deck + Superstructure + Substructure}{27}\right) \tag{15}$$

$$\text{Cul Score} = \left(1 - \frac{Culvert\ condition\ rating}{9}\right) \tag{16}$$

Where:

DSS = Deck, Superstructure, Substructure

SI_L = Local Severity Index

SI_B = Bridge Severity Index

Q_i = Quantity in condition state i (i= 1,2,3,4)

WF_i = Weighting Factor

I_e = Element Importance

Q_e = Total Element Quantity

Table 4-15: TxDOT Opinion Weights of Bridge Components

Element Group	TxDOT Opinion Weights
Superstructure	0.24
Substructure	0.24
Decks and Slabs	0.24
Bearings	0.10
Joints	0.08
Railings	0.05
Wearing Surfaces, Protective Coatings, Concrete Reinforcing Steel Protective System	0.03
Approach Slabs	0.02

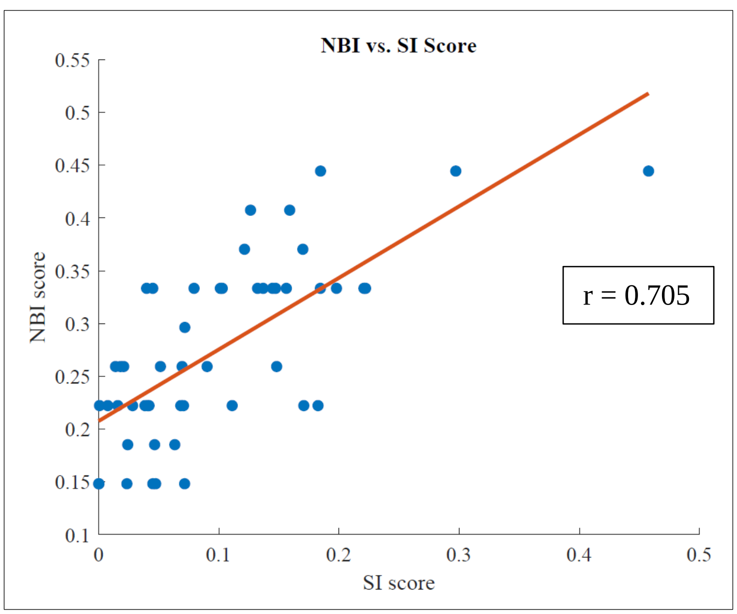


Figure 4-7: Correlation Between NBI Scores versus SI Scores for Bridges and Culverts

Table 4-16: Load Restriction Factor (HS-20)

Criteria	Index Score
Operating Rating (OR) or Inventory Rating (IR) < 3T	1
OR Rating Factor <1	1
3T$\leq IR \leq 36$	$-\frac{1}{33} * IR + \frac{12}{11}$
OR or IR ≥ 36 T	0

Table 4-17: Specialized Hauling Vehicles

Criteria	Index Score
Rating Factor (RF) for Operating Rating < 1	1
Rating Factor (RF) for Inventory Rating < 1	1- RF
Rating Factor for Inventory or Operating Rating ≥ 1	0

Table 4-18: Emergency Vehicles

Criteria	Index Score
Rating Factor for Operating Rating < 1	1
Rating Factor for Operating Rating ≥ 1	0

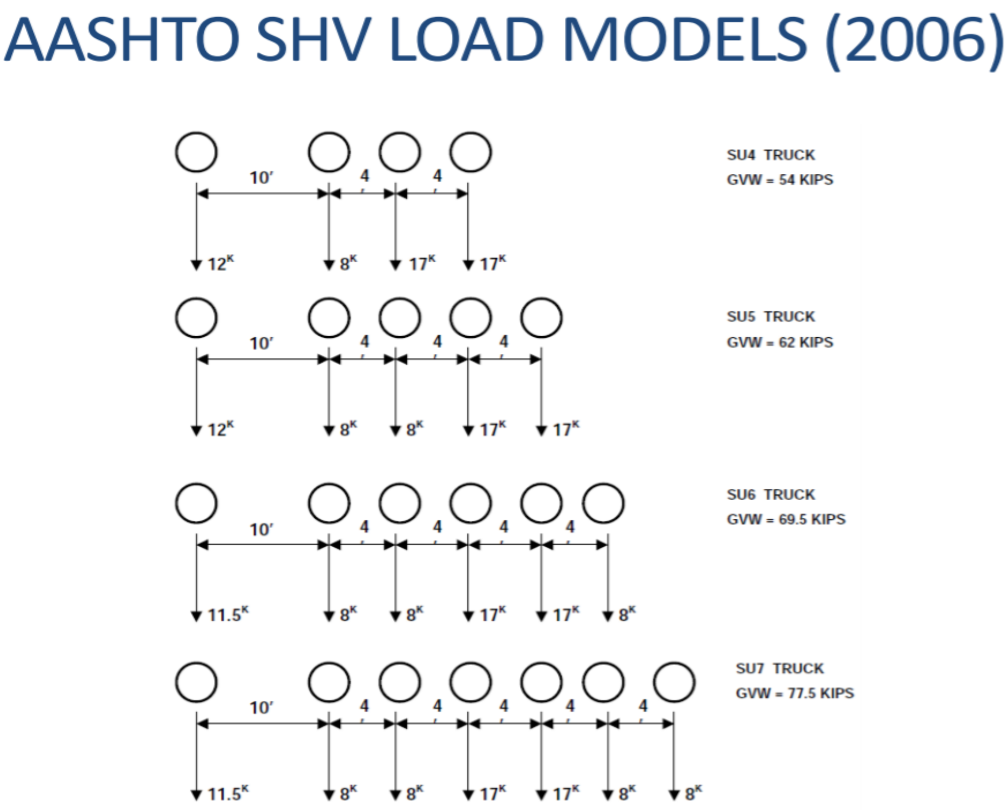


Figure 4-8: AASHTO SHV Load Models (AASHTO, 2016)

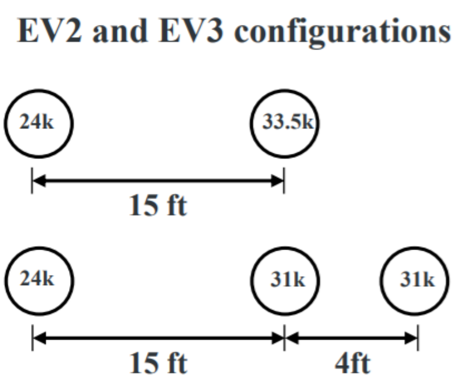


Figure 4-9: EVs Configuartions (AASHTO, 2016)

4.4.2 Cost Factor

The cost factor considers the ratio of the elements repair cost and replacement cost. The cost index is calculated by only considering the bridge elements with an SI of greater than or equal to 0.33. After the cost of repair and cost of replacement are input by the user, the cost index is calculated by summing the cost of repair (of each element with SI > 0.33) and multiplying by the total quantity, divided by the sum of the cost of replacement multiplied by the total quantity. This formula is shown in Equation 17.

It is important to note that if the user decides to run 100 bridges using the On-system formula, each bridge should have a value for the cost index to get a fair prioritization output. If a bridge does not have any values input to calculate the cost index, the cost index would be assumed to be zero.

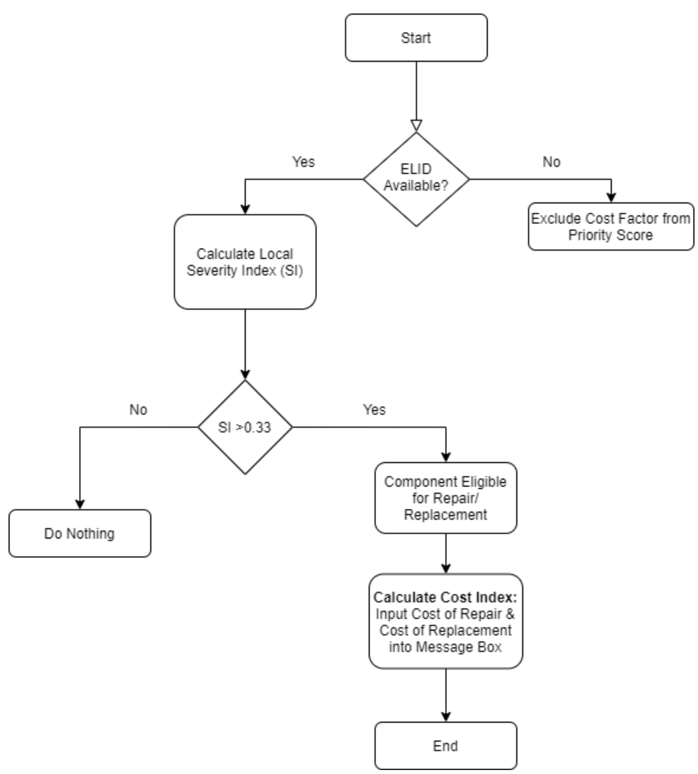


Figure 4-10: Cost Factor Flowchart

$$\text{Cost Index} = \frac{\sum Elements\ Repair\ Cost_i * Quantitiy\ in\ CS_{2,3,4}}{\sum Elements\ Replacement\ Cost_i * Total\ Quantity} \quad (17)$$

4.4.3 Age Factor

Bridge age data was obtained from the TxDOT GIS Open Data Portal (2021). From Figure 4-11, it is observed that the bridge sufficiency rating steadily decreases by approximately 3% from a bridge age of 0-75 years. From 76-100 years, the average sufficiency rating has dropped by approximately 9%. Based on Figure 4-11, an index score between zero and 1 was created for the four bridge groups as shown in Table 4-19.

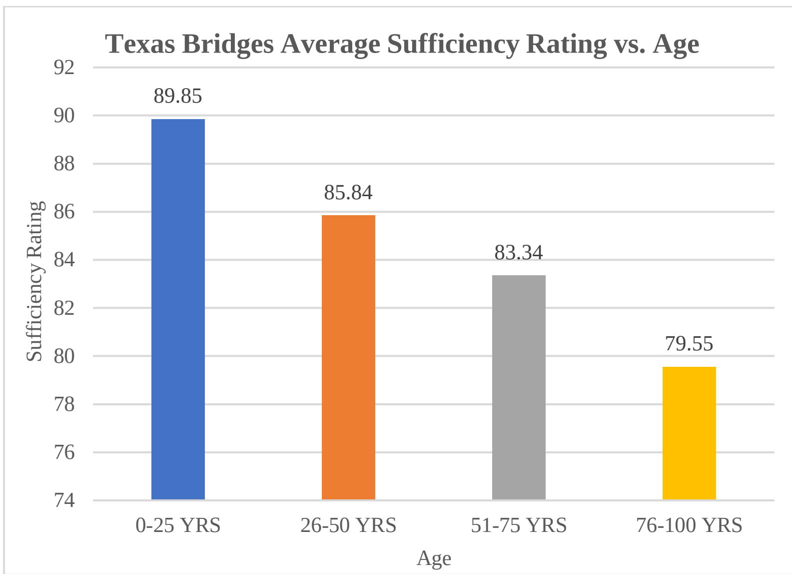


Figure 4-11: Texas Bridges Average Sufficiency Rating vs. Age

Table 4-19: Age Factor Index Scoring

Age Factor	
Bridge Age	**Index Score**
0 – 25 Years	0
26 - 50 Years	0.39
51 – 75 Years	0.63
76 – 100 Years	1

4.4.4 Importance

The importance factor incorporates the historical significance (Table 4-21) of the bridge and also considers unique features of the bridge using the *Main Span Type* NBI Item 43.1. If the first digit of Item 43.1 is 7 or 8 or if the 2nd digit of Item 43.1 is 2, 3, 4, 5, 6, or 7, then Special Bridge index = 1, otherwise, Special Bridge index = 0 (TxDOT, 2019). The overall importance index criteria is shown in Figure 4-12.

Table 4-20: Historical Importance Criteria

Code	Description
1	Bridge is on the National Register of Historic Places. (Listing provided by the Historic Preservation Office).
2	Bridge is eligible for the National Register of Historic Places. (Not used unless specifically instructed).
3	Bridge is at least 40 years old and meets one or more of the following qualifications: • Is a pin-connected or otherwise unique truss, a suspension bridge, an arch bridge, or is made of cast iron. • Demonstrates unique architectural or engineering design, or artistic embellishment such as cast iron or steel finials and fretwork, or elaborate concrete form work. • Is a "one of a kind" design.
4	Historical significance is not determinable at this time, but is at least 40 years old.
5	Bridge is not eligible for the National Register of Historic Places, or is not 40 years old.

Table 4-21: Historical Importance Index Values

Historical Importance	
Code	**Index Score**
1	1
2	0.75
3	0.5

4	0.25
5	0

- Index scores will be based on historical importance and special bridges.
  - If Historical significance Index > 0, and Special Bridge Index = 0, Importance Index = Historical Significance Index.
  - If Historical importance > 0, and Special Bridge Index = 1, Importance Index = 1.
  - If Historical significance Index = 0, and Special Bridge Index = 1, Importance Index = 1.

Figure 4-12: Importance Index Criteria (TxDOT, 2019)

4.4.5 Ease of Repair/Replacement

The ease of repair/replacement (EROR) is based on the component damaged and feature crossed. This factor was used for bridges which have local SI values greater than or equal to 0.33. The EROR index formulas are shown in Equations 18 and 19. An example of the user inputs showing the relative component weights of the bridge elements and the weights for the features crossed are shown in Tables 4-22 and 4-23. These bridges will be considered for repair or replacement. The flowchart for the EROR factor is shown in Figure 4-13.

$$\text{EROR Index} = 0.5*\text{Component Damaged} + 0.5*\text{Features Intersected} \quad (18)$$

$$\text{Component Damaged} = \frac{\sum Local\ SI * Relative\ Element\ Weight}{\sum Relative\ Element\ Weight} \quad (19)$$

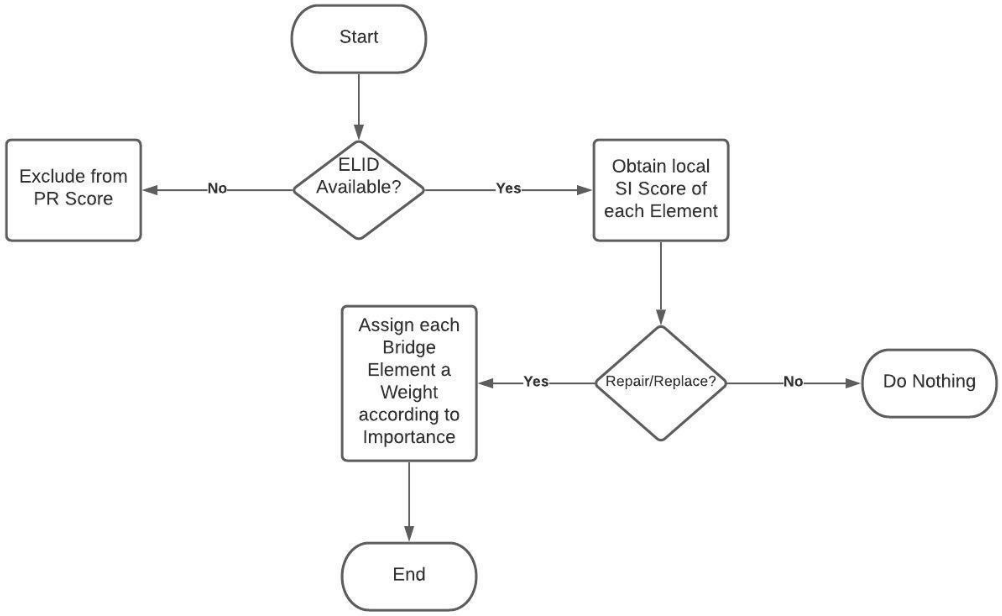


Figure 4-13 – Flowchart for EROR Factor

Table 4-22: Relative Component Weights

Component Damaged	Relative Weights (User Input)
Superstructure	0.24
Substructure	0.24
Decks & Slabs	0.24
Culvert	0.24
Bearings	0.1
Joints	0.08
Railings	0.05
Wearing Surfaces & Protective Coatings & Concrete R	0.03
Approach Slabs	0.02

Table 4-23: Weights for Features Intersected

Feature Intersected	Weight
Waterway	0.67
Roadway	0.33
Railroad	1

4.4.6 Risk Factor

The Risk Factor measures the susceptibility of the bridge to scour as well as its Strategic Highway Network Designation (STRAHNET). A linear index scoring method was used to distribute the index scores for the scour critical bridge item. The weights of the STRAHNET highway designation was provided by expert engineers as shown in Table 4-24.

Table 4-24: Risk Factor

Risk Factor				
Sub-Factors	**Scour Critical Bridge (Item 113)**	**STRAHNET Highway Designation**		
Index Score	IF Item 113 = 0, 1, 2 THEN Index value =1	**Code**	**Description**	**Index Score**
	IF $3 \le Item\ 113 \le 9\ THEN\ Index\ Score = -\frac{1}{6}(Scour\ Critical\ Score) + 1.5$	0	Not STRAHNET route	0.125
		1	Interstate STRAHNET route	1
		2	Non-Interstate STRAHNET route	0.67
		3	STRAHNET connector route	0.33
Risk Score =	0.5*Scour Critical Index + 0.5*STRAHNET Highway Designation Index			

4.4.7 Geometry Factor

The Geometry Factor was developed as a similar model to the geometry factor of the TxDOT Sufficiency Rating in the Bridge Inspection Manual (2019). The weights were adjusted to reflect the 0-1 scale of the decision tool. The geometry factor is calculated using Equations 20 – 24 and Tables 4-25 through 4-27.

Geometry Index = 0.45*R + 0.45*W + 0.1*V (20)

R = Rating Reduction = $\frac{A + B + C + D + E + F}{6}$ (21)

W = Roadway Width Insufficiency = 0.25*G + 0.75*H for Bridges (22)

V = Vertical Clearance Insufficiency

Criteria for Rating Reduction:

Table 4-25: Rating Reduction (TxDOT, 2019)

Item 58 (Deck Condition)	**Item 67 (Structural Evaluation)**	**Item 68 (Deck Geometry)**	**Item 69 (Underclearances)**	**Item 71 (Waterway Adequacy)**	**Item 72 (Approach Roadway Alignment)**
$\leq 3, \text{then C} = 1$	$\leq 3, \text{then C} = 1$	$\leq 3, \text{then C} = 1$	$\leq 3, \text{then C} = 1$	$\leq 3, \text{then C} = 1$	$\leq 3, \text{then C} = 1$
$= 4, \text{then C} = 0.6$	$= 4, \text{then C} = 0.6$	$= 4, \text{then C} = 0.5$	$= 4, \text{then C} = 0.5$	$= 4, \text{then C} = 0.5$	$= 4, \text{then C} = 0.5$
$= 5, \text{then C} = 0.2$	$= 5, \text{then C} = 0.2$	$= 5, \text{then C} = 0.25$	$= 5, \text{then C} = 0.25$	$= 5, \text{then C} = 0.25$	$= 5, \text{then C} = 0.25$
$\geq 6, \text{then C} = 0$	$\geq 6, \text{then C} = 0$	$\geq 6, \text{then C} = 0$	$\geq 6, \text{then C} = 0$	$\geq 6, \text{then C} = 0$	$\geq 6, \text{then C} = 0$
$= \text{N}, \text{then C} = 0$	$= \text{N}, \text{then C} = 0$	$= \text{N}, \text{then C} = 0$	$= \text{N}, \text{then C} = 0$	$= \text{N}, \text{then C} = 0$	$= \text{N}, \text{then C} = 0$

Criteria for Roadway Width Insufficiency (G+H):

Find X and Y:

$$Y = \frac{\text{BRIDGE ROADWAY WIDTH CURB TO CURB (Item 51)}}{\text{LANES ON STRUCTURE (Item 28)}} \quad (23)$$

$$X = \frac{\text{ADT (Item 29)}}{\text{LANES ON STRUCTURE (Item 28)}} \quad (24)$$

Table 4-26: Roadway Insufficiency

(1) For all bridges except culverts	(2) For one-lane bridges including one-lane culverts	(3) For bridges with two or more lanes (including culverts)
• If Item 43.4 (CULV_MEMB_TYPE) is blank or 0 and; • If Item 51 (BRDG_RDWAY_WIDTH_CURB_CURB) + 2 ft < Item 32 (APRCH_RDWAY_WIDTH), then G = 1 • If Item 51 (BRDG_RDWAY_WIDTH_CURB_CURB) + 2 ft • Item 32 (APRCH_RDWAY_WIDTH), then G = 0.	• If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 01 and; • If Y < 14, then H = 1 • If 14 ≤ Y but < 18, then H = 0.25 [(18 – Y)/4]. • If Y ≥ 18, then H = 0.	• If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 02 and Y ≥ 16, then H = 0. • If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 03 and Y ≥ 15, then H = 0. • If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 04 and Y ≥ 14, then H = 0. • If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 05 and Y ≥ 12, then H = 0. If any one of the preceding conditions is met, do not continue trying to determine H because no lane width reductions are necessary. Otherwise, determine H based on the following: values for X and Y: • If X≤ 50 and Y < 9, then H = 0.5 • If X≤ 50 and Y≥ 9, then H = 0. • If 50 < X ≤125 and Y < 10, then H = 1. • If 50 < X ≤125 and 10 ≤Y < 13, then H = 0.33 [(13 - Y)/3] • If 50 < X ≤125 and Y ≥13, then H = 0 • If 125 < X ≤375 and Y < 11, then H = 1 • If 125 < X ≤375 and 11≤ Y < 14, then H = 0.33 [(14 - Y)/3] • If 125 < X ≤375 and Y ≥14, then H = 0 • If 375 < X≤ 1350 and Y < 12, then H = 1 • If 375 < X≤ 1350 and 12 ≤ Y < 16, then H = 0.25 [(16 - Y)/4] • If 375 < X ≤1350 and Y ≥16, then H = 0 • If X > 1350 and Y < 15, then H =1 • If X > 1350 and 15≤ Y < 16, then H = 1 (16 - Y) • If X > 1350 and Y ≥16, then H = 0

V is a Vertical Clearance Insufficiency set by the following:

Table 4-27: Vertical Clearance Criteria

If Item 100 (STRAHNET Highway Designation) > 0 and;	
Item 53 (Minimum Vertical Clearance Over Bridge Deck (ft)) > 1600 then	V = 0
Item 53 (Minimum Vertical Clearance Over Bridge Deck (ft)) < 1600 then	V = 1
If Item 100 (STRAHNET Highway Designation) = 0 and;	
Item 53 (Minimum Vertical Clearance Over Bridge Deck (ft)) > 1400 then	V = 0
Item 53 (Minimum Vertical Clearance Over Bridge Deck (ft)) < 1400 then	V = 1

4.4.8 Public Use

The Public Use Factor considers two main criteria: Traffic and Functional Classification. Under the Traffic sub-factor, the ADT and Bridge Detour Length are considered. The formula for the Public Use Factor is shown in Table 4-28.

The Public Use Factor is dependent on the Traffic and Functional classification of the roadway. The subfactors of the Traffic index include the ADT and Detour Length criteria. The ADT criteria considers two cases: route carried on the structure (Item 5.1 = 1) and route carried under the structure (Item 5.1 = 2). The ADT graph was plotted using bridge data from the TxDOT GIS Open Data Portal. Approximately 4000 bridges were used to plot the graph. The bridge ADT values were then grouped into deciles and appropriate index scores were assigned to the deciles. Due to the large number of bridges over having an ADT of over 31416 vehicles per hour, a step function was created at this threshold. Similarly for the Intersecting Route ADT, a step function was created at 23000 vehicles per hour.

Table 4-28: Public Use Factor

<table>
<tr><td colspan="3">Public Use = 0.5*Traffic + 0.5*Functional Classification</td></tr>
<tr><th>Traffic</th><th colspan="2">Functional Classification</th></tr>
<tr><td rowspan="9">Traffic Index = 0.5*ADT + 0.5*Detour Length

ADT Index = $0.0231*ADT^{0.3421}$

Detour Length Index = $\frac{Det}{9}$ for Detour Lengths of 0-9.
IF Detour Length > 9, THEN Index Score = 1 (Signifying the maximum detour length considered to be “extreme”)

IF Item 5.1 =1
• Bypass Detour Length
• ADT (Index Value = 1 after ADT = 31416) → Refer to Graph 1
IF Item 5.1 = 2
• Intersecting Route ADT (Index Value = 1 after ADT = 23000) → Refer to Graph 2
• Intersecting Route Bypass Detour Length</td><td>Inventory Route Functional Classification</td><td>Index Value</td></tr>
<tr><td>Interstate</td><td>1.000</td></tr>
<tr><td>Other Freeway and Expressway</td><td>0.875</td></tr>
<tr><td>Other Principal Arterial</td><td>0.750</td></tr>
<tr><td>Minor Arterial</td><td>0.625</td></tr>
<tr><td>Collector</td><td>0.500</td></tr>
<tr><td>Major</td><td>0.375</td></tr>
<tr><td>Minor</td><td>0.250</td></tr>
<tr><td>Local</td><td>0.125</td></tr>
</table>

ADT Score

IF Item 5.1 = 1, use Figure 4-13

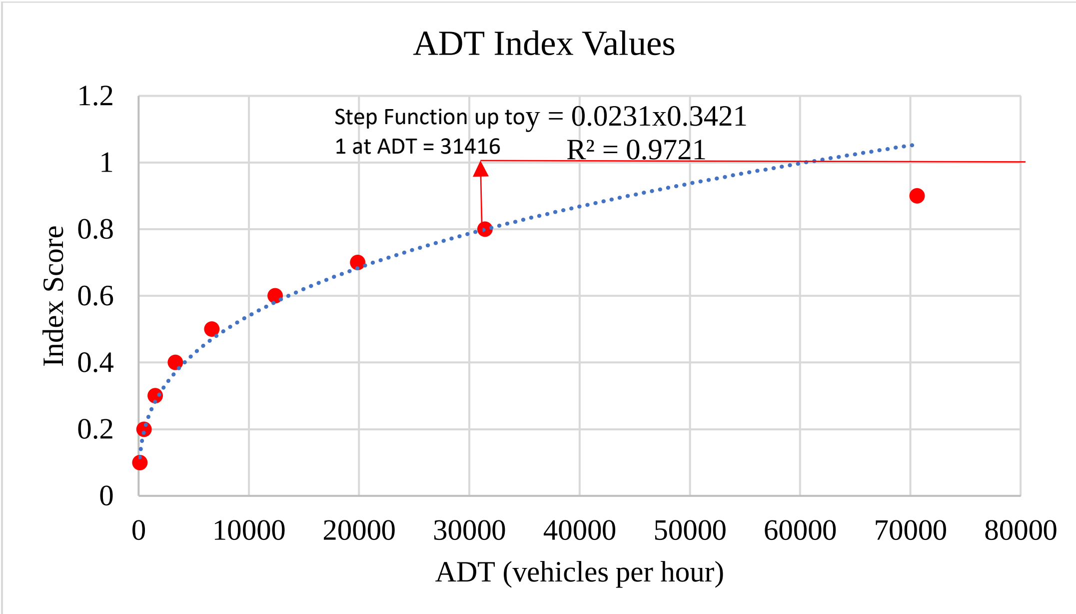


Figure 4-13: ADT Index Values

IF Item 5.2 = 2, use Figure 4-14

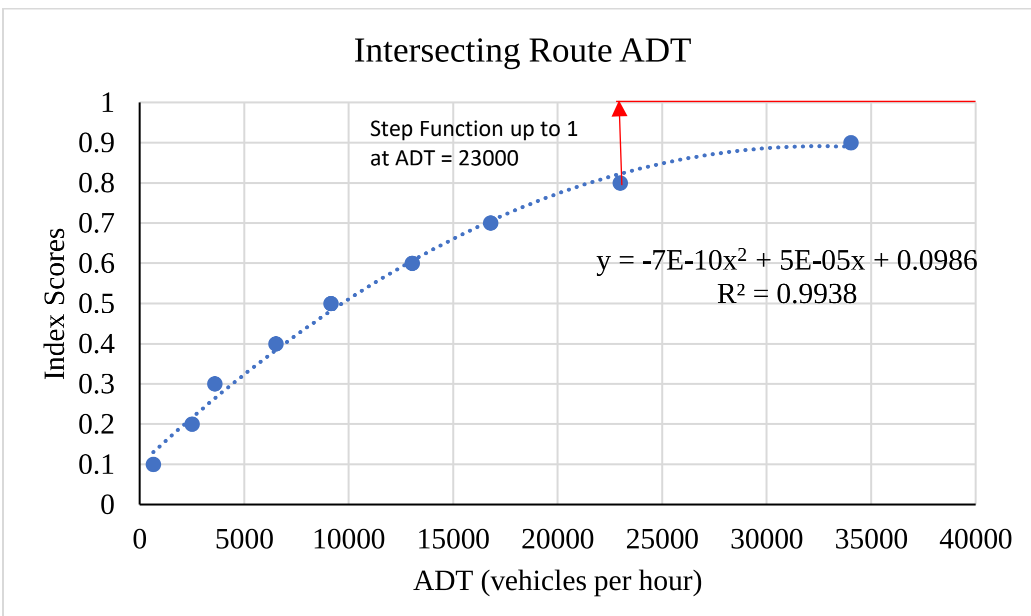


Figure 4-14: Intersecting Route ADT Index Values

4.5 Determination of the Final Factor Weights

The AHP was used as an initial process to determine the average factor weights, however, more concrete input was given by expert Engineers at TxDOT. TxDOT reviewed the weights suggested by UTA and provided appropriate input. The Opinion weights from TxDOT are shown in Tables 4-29 through 4-36.

Table 4-29: TxDOT Opinion On-System Weights

Factor	Analytic Weights (0 - 100)	Opinion Weight (0 - 100)
Condition	3.911	3.9
Geometry	2.155	1.8
Public Use	1.270	0.9
Risk	1.270	1.6
Cost	0.586	0.3
Age	0.370	0.8
EROR	0.238	0.3
Importance	0.200	0.4
Sum	**10.00**	**10.00**

Table 4-30: TxDOT Opinion Off-System Weights

Factor	Analytic Weights	Opinion Weights (0 - 100)
Condition	3.958	3.9
Geometry	2.322	1.8
Public Use	1.422	1.5
Risk	1.422	1.6
Age	0.493	0.8
Importance	0.383	0.4
Sum	**10.00**	**10.00**

Table 4-31: Elemental Importance Weights

Element Group	Analytic Relative Weights	Opinion RELATIVE Weights (0-1)
Superstructure	0.238	0.24
Substructure	0.238	0.24
Decks and Slabs	0.238	0.24
Bearings	0.106	0.1
Joints	0.080	0.08
Railings	0.048	0.05
Protective Coatings, Concrete Reinforcing Steel Protective System	0.032	0.03
Approach Slabs	0.020	0.02
Insert Sum	1.00	1.00

Table 4-32: Risk Factor

<table>
<tr><th colspan="6">Risk Factor</th></tr>
<tr><th>Sub-Factors</th><th>Scour Critical Bridge (Item 113)</th><th colspan="4">STRAHNET Highway Designation</th></tr>
<tr><th rowspan="5">Index Score</th><td>IF Item 113 = 0, 1, 2 THEN Index value =1</td><th>Code</th><th>Description</th><th>Index Score</th><th>Opinion Weight (0-1)</th></tr>
<tr><td rowspan="4">IF $3 \leq Item\ 113 \leq 9\ THEN\ Index\ Score = -\frac{1}{6}(Scour\ Critical\ Score) + 1.5$</td><td>0</td><td>Not STRAHNET route</td><td>0</td><td>0.125</td></tr>
<tr><td>1</td><td>Interstate STRAHNET route</td><td>1</td><td>1</td></tr>
<tr><td>2</td><td>Non-Interstate STRAHNET route</td><td>0.67</td><td>0.67</td></tr>
<tr><td>3</td><td>STRAHNET connector route</td><td>0.33</td><td>0.33</td></tr>
</table>

Table 4-33: Risk Score Opinion Weights

<table>
<tr><th rowspan="3">Risk

Score =</th><td>(c)*Scour Critical Index + (d)*STRAHNET Highway

Designation Index</td><th colspan="2">Opinion Weight (0-1)</th></tr>
<tr><td>(c) = 0.5 (suggested weight)</td><td>(c)</td><td>0.5</td></tr>
<tr><td>(d) = 0.5 (suggested weight)</td><td>(d)</td><td>0.5</td></tr>
</table>

Table 4-34: Age Factor Opinion Weights

Age Factor		
Bridge Age	**Index Score**	**Opinion Weight (0-1)**
0 – 25 Years	0	0
26 - 50 Years	0.39	0.39
51 – 75 Years	0.63	0.63
76 – 100 Years	1	1

Table 4-35: Historical Importance Opinion Weights

Historical Importance		
Code	**Index Score**	**Opinion Weights (0-1)**
1	1	1
2	0.75	0.75
3	0.5	0.5
4	0.25	0.25
5	0	0

Table 4-36: Public Use Opinion Weights

Functional Classification		
Inventory Route Functional Classification	**Index Value**	**Opinion Weights (0-1)**
Interstate	1	1
Other Freeway and Expressway	0.875	0.875
Other Principal Arterial	0.75	0.75
Minor Arterial	0.625	0.625
Collector	0.5	0.5
Major	0.375	0.375
Minor	0.25	0.25
Local	0.125	0.125

4.6 Test Decision Tool

TxDOT provided UTA with a list of 25 bridges for testing. However, 23 bridges were present in the bridge inventory. The priority scores for each bridge were generated and were assessed and analyzed according to the actual condition/attributes of the bridge and the results are shown in Table 4-37.

Table 4-37: Off-System Formula Bridge Test

BRIDGE_ID	Condition Factor	Age Factor	Public Use Factor	Risk Factor	Importance Factor	Geometry Factor	Off System PR	Rank
22200036303014	0.72	0.63	0.44	0.06	0.50	0.14	4.52	1
022490AA0113003	0.70	0.39	0.38	0.15	0.00	0.26	4.33	2
21270001403194	0.39	0.63	0.65	0.50	0.50	0.07	4.10	3
20730133201010	0.35	0.63	0.43	0.56	0.50	0.21	3.96	4
21840031401074	0.33	0.63	0.68	0.50	0.50	0.04	3.87	5
20730199102003	0.35	0.63	0.48	0.40	0.50	0.19	3.73	6
21820000710057	0.22	0.63	0.65	0.15	0.75	0.27	3.36	7
022200BB0220002	0.33	1.00	0.18	0.15	0.50	0.28	3.32	8
21820073601004	0.31	0.63	0.48	0.15	0.50	0.22	3.24	9
22200000813263	0.19	0.63	0.53	0.50	0.50	0.07	3.14	10
22490001308054	0.27	0.39	0.61	0.34	0.50	0.02	3.04	11
21840000803316	0.19	0.39	0.53	0.50	0.00	0.02	2.66	12
22200017206269	0.17	0.63	0.63	0.06	0.50	0.11	2.59	13
22200017206067	0.22	0.63	0.44	0.06	0.50	0.10	2.50	14
022200ZL6785003	0.17	0.39	0.21	0.40	0.00	0.29	2.43	15
22200000813081	0.19	0.63	0.36	0.06	0.50	0.07	2.19	16
21270025905079	0.13	0.00	0.55	0.50	0.00	0.00	2.12	17
22490001306327	0.13	0.00	0.54	0.42	0.00	0.00	1.99	18
021270AA0125001	0.17	0.39	0.18	0.15	0.00	0.28	1.97	19
22490013407091	0.09	0.39	0.52	0.06	0.00	0.08	1.69	20
021840AA0435002	0.11	0.00	0.26	0.31	0.00	0.19	1.67	21
021820AA0222003	0.04	0.00	0.28	0.31	0.00	0.19	1.41	22
022200AA0657002	0.06	0.00	0.32	0.31	0.00	0.04	1.26	23

4.7.1 Results from the Comparison between Off-system and On-System Formula

The results indicate that the priority ranking remained the same for the 10 bridges, whether the on- or off-system formula is used. The results depict the same ranking for both formulas, although they had different PR scores. This means that both formulas are working in synchronism as intended.

Table 4-38: Priority Rating using On-System Formula

Bridge ID	Condition	Age	Public Use	Risk	EROR	Importance	Geometry	Cost	On-System PR	Rank
22200036303014	0.63	0.63	0.69	0	0.36	0.5	0.14	0.31	4.27	1
20730133201010	0.28	0.63	0.43	0.5	0.17	0.5	0.21	0.25	3.51	2
21840031401074	0.26	0.63	0.68	0.5	0.33	0.5	0.04	0.21	3.39	3
20730199102003	0.3	0.63	0.48	0.33	0.25	0.5	0.19	0.18	3.32	4
21820000710057	0.2	0.63	0.65	0.08	0.27	0.75	0.27	0.16	2.93	5
2182007361004	0.27	0.63	0.48	0.08	0.21	0.5	0.22	0.16	2.84	6
22490001308054	0.22	0.39	0.61	0.34	0.33	0.5	0.02	0.12	2.65	7
21840000803316	0.15	0.39	0.78	0.5	0.23	0	0.02	0.08	2.54	8
22200017206067	0.15	0.63	0.69	0	0.17	0.5	0.1	0.05	2.16	9
22490013407091	0.06	0.39	0.52	0	0.17	0	0.08	0	1.21	10

Table 4-39: Priority Rating using Off-System Formula

Bridge ID	Condition	Age	Public Use	Risk	Importance	Geometry	Off-System PR	Rank
22200036303014	0.72	0.63	0.69	0	0.5	0.14	4.799	1
20730133201010	0.35	0.63	0.43	0.5	0.5	0.21	3.892	2
21840031401074	0.33	0.63	0.68	0.5	0.5	0.04	3.883	3
20730199102003	0.35	0.63	0.48	0.33	0.5	0.19	3.659	4
21820000710057	0.22	0.63	0.65	0.08	0.75	0.27	3.251	5
2182007361004	0.31	0.63	0.48	0.08	0.5	0.22	3.157	6
22490001308054	0.27	0.39	0.61	0.34	0.5	0.02	3.06	7
21840000803316	0.19	0.39	0.78	0.5	0	0.02	3.059	8
22200017206067	0.22	0.63	0.69	0	0.5	0.1	2.777	9
22490013407091	0.07	0.39	0.52	0	0	0.08	1.509	10

4.7.2 Priority Rating Results Using Off-System Priority Rating

The results from the test bridges depicted expected values in accordance with the visual inspection of the bridge condition. Key details about the bridges which ranked 1st (worst condition), 12th (middle rank), and 23rd (best condition) were listed along with the images on the bridges.

The bridge which ranked first in the priority list, as shown in section 4.7.2.1 implied that the bridge is most in need of repair/replacement (worst condition) as compared to the other bridges in the list. A detailed description can be found in Table 4-47. This bridge had an unofficial sufficiency rating of 46.6 and NBI condition ratings depicting poor condition and advanced deterioration of the major structural members (deck, superstructure, and substructure). It also contains low load ratings, which results in LRFs of less than 1 for both the Inventory and Operating levels. Also, the photos in Figure 4-17 depict major damages to the structure, for example, spalling and delamination in the bridge soffit, rusting of steel members and major damages to the exterior beam. This bridge displayed the worst condition in the test sample based on the visual inspection and honored this rating using the priority rating formula.

The middle-ranked bridge as shown in Figure 4-16, displayed median characteristics as expected as compared to the bridge in "worst" condition and "best" condition. It had an unofficial sufficiency rating of 74.1 and NBI condition ratings for the decks, superstructure, and substructure of 6, 6, and 5, respectively. A more detailed description can be found in Table 4-48. These NBI condition ratings depict fair condition. The load rating factors for the Inventory and Operating ratings were both greater than or equal to 1, depicting that the bridge is safely able to carry the loads. Figure 4-18 shows images of the condition of the middle-ranked bridge.

The bridge which ranked last in the list depicted the "best" condition as shown in Figure 4-17. It has an unofficial sufficiency rating of 91.6 and NBI condition ratings for the deck, superstructure, substructure of 8, 8, and 8, respectively. The bridge load rating factors for both the Inventory and Operating levels were well over 1. A more detailed description can be found in Table 4-49. The visual inspection of the bridge also displayed very good conditions for all bridge components. Moreover, this is a relatively new bridge built in 2018. Images of the best ranked bridge are shown in Figure 4-19.

4.7.2.1 A closer Look at Bridge which Ranked 1st ("worst" condition)

Table 4-40: 22200036303014 Bridge Description

Parent Asset	TARRANT - 220
Asset Name	22200036303014
Asset Type	Bridge
TXDOT SI&A System Designation	1 - On System
TXDOT SI&A Bridge Description	4 Continuous Span Steel I-Beam Bridge on Concrete Supports Concrete Supports
NBI 007: Facility Carried by Structure	N SYLVANIA AVE
NBI 006: Feature Intersected	SH 121
NBI 029: Average Daily Traffic (ADT)	11374
NBI 064: Operating Rating	32
NBI 066: Inventory Rating	20
NBI 58 Deck/NBI 59 Superstructure/NBI 60 Substructure	5 - Fair Condition (minor section loss) 4 - Poor Condition (advanced deterioration) 6 - Satisfactory Condition (minor deterioration)
Unofficial Sufficiency Rating	46.6
Status	1-SD
NBI 027: Year Built	1963

Figure 4-15: Condition of “Worst” Bridge: (a) Close up of damage to east exterior beam (b) Rusting of steel members at south abutment; (c) Spalling and delamination in soffit; and (d) Tree growing in rip rap under bridge (AssetWise, 2021)

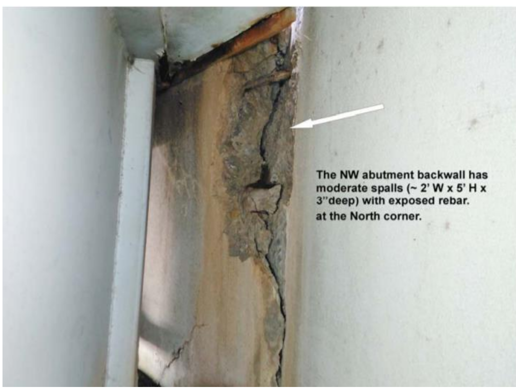
4.7.2.2 A closer look at the Bridge ranked 12th (middle rank)

Table 4-41: 21840000803316 Bridge Description

Parent Asset	PARKER-184
Asset Name	21840000803316
Asset Type	Bridge
TXDOT SI&A System Designation	1 - On System
TXDOT SI&A Bridge Description	3 - Continuous Span Steel Plate Girder on Concrete Caps & Columns @ Var. Left Forward Skew (avg. ~ 61°)
NBI 007: Facility Carried by Structure	IH 20 EB
NBI 006: Feature Intersected	IH 30 EBFR
NBI 029: (ADT)	99739
NBI 064: Operating Rating	60
NBI 066: Inventory Rating	36
NBI 041: Structure Open, Posted, or Closed to Traffic	A - Open
NBI 58 Deck/NBI 59 Superstructure/NBI 60 Substructure	6 - Satisfactory Condition (minor deterioration) - 6 - Satisfactory Condition (minor deterioration) - 5 - Fair Condition (minor section loss)
Unofficial Sufficiency Rating	74.1
Status	0 - ND
NBI 027: Year Built	1986

(a)

(b)



(c)

(d)

(e)

Figure 4-16: Condition of “Middle Ranked” Bridge: (a) IH 30 EB FR (b) Spalled SE abutment cap; (c) Spalled NW abutment backwall; (d) Replaced SE approach slab; and (e) Impact damage guard fence (AssetWise, 2021)

4.7.2.3 A closer look at the Bridge ranked 23rd ("best" condition)

Table 4-42: 022200AA0657002 Bridge Description

Parent Asset:	TARRANT - 220
Asset Name:	022200AA0657002
Asset Type:	Bridge
TXDOT SI&A System Designation:	2 - Off System
TXDOT SI&A Bridge Description:	3- Simple Span Prestressed I-Girder Bridge
NBI 007: Facility Carried by Structure	BURLESON-RETTA RD
NBI 006: Feature Intersected:	VILLAGE CREEK
NBI 029: Average Daily Traffic (ADT)	2715
NBI 064: Operating Rating	60
NBI 066: Inventory Rating	36
NBI 041: Structure Open, Posted, or Closed to Traffic	A - Open
NBI 58 Deck/NBI 59 Superstructure/NBI 60 Substructure:	8 - Very Good Condition (no problems noted) - 8 - Very Good Condition (no problems noted) - 8 - Very Good Condition (no problems noted)
NBI 061: Channel and Channel Protection	7 - Bank protection needs minor repairs
NBI 113: Scour Critical Bridges	6 - Lacking scour evaluation and/or documentation
Unofficial Sufficiency Rating:	91.6
Status:	0 - ND
NBI 027: Year Built	2018

(a)

(b)

(c)

(d)

(e)

Figure 4-17: Condition of "Best" Bridge: (a) Elevation looking NW; (b) Road overlooking east; (c) Superstructure; (d) Stream under looking north; and (e) Timber bracing/forms at East bent (AssetWise, 2021)

4.7 Discussion of Results for Target Bridges and Heat Graph Scheme

A Heat Graph scheme as shown in Tables 4-43 and 4-44 to categorize the target bridges with color coding (green, yellow, red) was used as appropriate. The decision thresholds were given by the average scores of the condition factor.

Table 4-43: Priority Ranking Score Heat Map

Priority Ranking Score Heat Map	
Score	**Decision**
<2.5	Good Condition
2.5 ≤ PR < 5.5	Repair Recommended
≥ 5.5	Replacement Recommended

Table 4-44: Bridge Decision based on Local SI and NBI Scores

IF ELID Available	
Legend	
Do Nothing	local SI < 0.33
Repair	0.33 < local SI < = 0.67
Replace	SI > 0.67
ELID Not Available	
Legend	
Do Nothing	NBI Cond/Appr Rtg >= 7
Repair	NBI Cond/Appr Rtg = 5, 6
Replace	NBI Cond/Appr Rtg <= 4

4.8 Comparison Between the Priority Ranking Using the SR and PR

Table 4-45 shows the comparison between the bridge ranking using the SR and PR. Bridge 22200036303014 ranked first using the PR and second using the SR. This bridge was deemed to be in the worst condition according to the PR and similar for the SR. Table 4-46 shows that this bridge has NBI condition ratings for the deck, superstructure, and substructure of 5, 4, and 6, respectively. It has a PR of 4.52 and a SR of 47. According to the SR, the bridge is eligible for replacement. Contrarily, according to the scale of the PR, the bridge should be repaired. However, based on the NBI condition ratings, since the superstructure has a rating of 4 (poor condition), it is recommended for replacement.

Secondly, Bridge 22490001308054 was the middle-rank according to the PR, and the 12th rank according to the SR. Both the PR and SR gave similar rankings for this structure.

The 20th (last) ranked bridge according to the PR was deemed to be in the best condition. Bridge 022200AA0657002 has NBI condition ratings for the deck, superstructure, and substructure of 8,8, and 8, respectively and Inventory and Operating ratings of 36 and 60. A visual representation of the condition of the bridge can also be seen in Table 4-48. Contrarily, this bridge ranked 14th using the SRS. However, the bridge which ranked 20th using the SRS, ranked 19th using the PR.

Table 4-45: SR versus PR Ranking

Bridge ID	Priority Rating	PR RANK	Sufficiency Rating	SR Rank
22200000813263	3.14	9	80	11
22200017206269	2.59	12	93	17
22490001308054	3.04	10	90	12
21840000803316	2.66	11	74	9
22200017206067	2.50	13	68	6

022490AA0113003	4.33	2	22	1
22490001306327	1.99	16	92	16
21270025905079	2.12	15	92	15
22200000813081	2.19	14	95	18
21270001403194	4.10	3	68	5
022200BB0220002	3.32	7	55	3
22200036303014	4.52	1	47	2
21840031401074	3.87	5	73	8
21820073601004	3.24	8	75	10
20730133201010	3.96	4	69	7
20730199102003	3.73	6	68	4
021820AA0222003	1.41	19	99	20
021840AA0435002	1.67	18	91	13
022200AA0657002	1.26	20	92	14
22490013407091	1.69	17	95	19

Table 4-46: Bridge 22200036303014 Properties

NBI Item	Condition Rating
Deck	5
Superstructure	4
Substructure	6
Inventory Rating Gross Loading (Tons)	26
Operating Rating Gross Loading (Tons)	43

Table 4-47: Bridge 22490001308054 Properties

NBI Item	Condition Rating
Deck	7
Superstructure	6
Substructure	6
Inventory Rating Gross Loading (Tons)	28
Operating Rating Gross Loading (Tons)	73

Table 4-48: Bridge 022200AA0657002 Properties

NBI Item	Condition Rating
Deck	8
Superstructure	8
Substructure	8
Inventory Rating Gross Loading (Tons)	36
Operating Rating Gross Loading (Tons)	60

4.9 Incorporating a Conversion Factor into the Decision Tool

To rate on-system and off-system bridges on the same scale, a conversion factor was implemented into the tool. The conversion factor was obtained using the average scores of the on-system and off-system bridges and was found to be 1.20. Table 4-49 shows a sample of a combination of on-system and off-system bridges with the normalized priority rating using the conversion factor.

Table 4-49: Normalized Priority Ratings Using the Conversion Factor

Asset Codes	Priority Rating (On - System)	Priority Rating (Off - System)	Normalized Priority Rating	Rank
22200000813263	2.56		3.07	10
22200017206269	2.09		2.50	13
22490001308054	2.51		3.01	11
21840000803316	2.29		2.75	12
22200017206067	2.05		2.46	14
022490AA0113003		4.33	4.33	2
22490001306327	1.51		1.82	19
21270025905079	1.79		2.14	17
22200000813081	1.99		2.39	16
21270001403194	3.54		4.25	4
022200ZL6785003		2.43	2.43	15
022200BB0220002		3.32	3.32	9
22200036303014	3.97		4.77	1
21840031401074	3.27		3.92	6
21820073601004	2.87		3.44	8
21820000710057	3.07		3.68	7
20730133201010	3.57		4.28	3
20730199102003	3.38		4.05	5
021270AA0125001		1.97	1.97	18
021820AA0222003		1.41	1.41	22
021840AA0435002		1.67	1.67	20
022200AA0657002		1.26	1.26	23
22490013407091	1.38		1.66	21

CHAPTER 5

EXCEL Based Decision Tool – BridgeRep

5.1 Description

An EXCEL-based decision tool was built to incorporate all the developed factors and generate priority scores for all bridges in the database for the Fort Worth District. The decision tool named BridgeRep has a user-friendly platform with clickable buttons to generate index scores for all factors, update required bridge inventory data, and generate normalized priority scores for a combination of on-system and off-system bridges. The name BridgeRep refers to bridge repair/replacement. The BridgeRep main dashboard is shown in Figure 5-1.

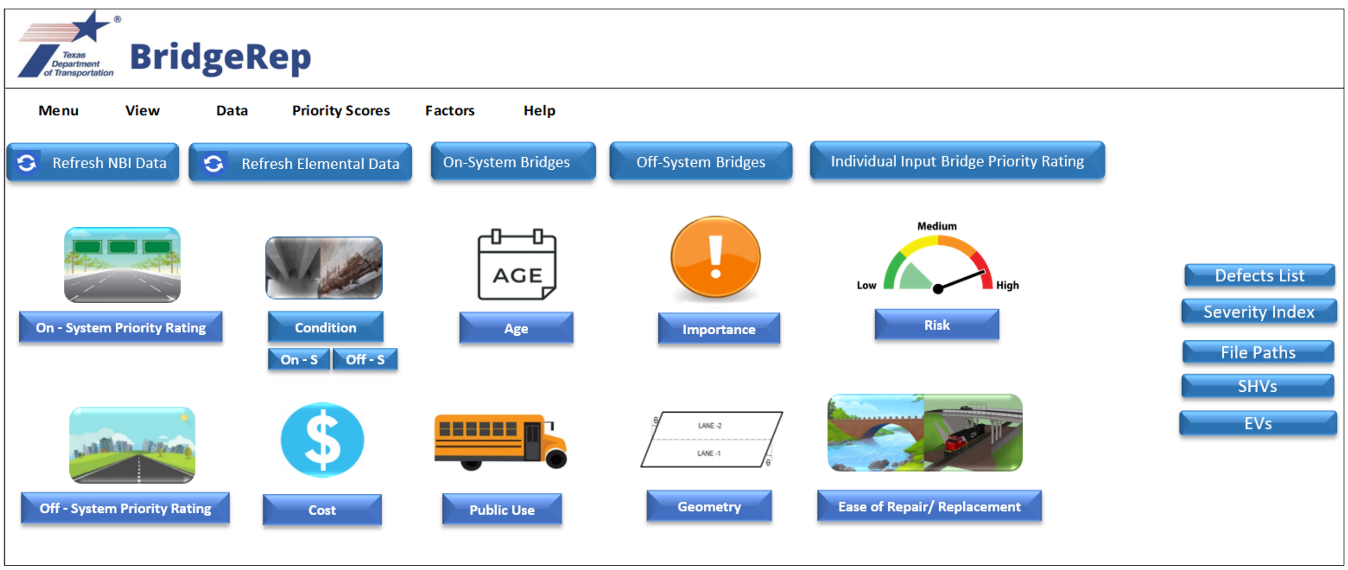


Figure 5-1: BridgeRep Main View

5.2 Features of BridgeRep

The BridgeRep software includes consist of a variety of features to provide a User-friendly and interactive experience. Some of these include smart buttons which are linked to the various spreadsheets and reference data. Smart buttons are also available to refresh data, calculate index scores, final priority scores, and update data.

On the BridgeRep Main dashboard as shown in Figure 5-2, Users can hover over the main menu options to navigate through the items. On most factor sheets, there is a dropdown menu option which references the formulas behind each factor as shown in Figures 5-3 and 5-4 Additionally, for specific factors like Cost and EROR, Users will be able to input values into the green shaded cells as shown in Figure 5-5.

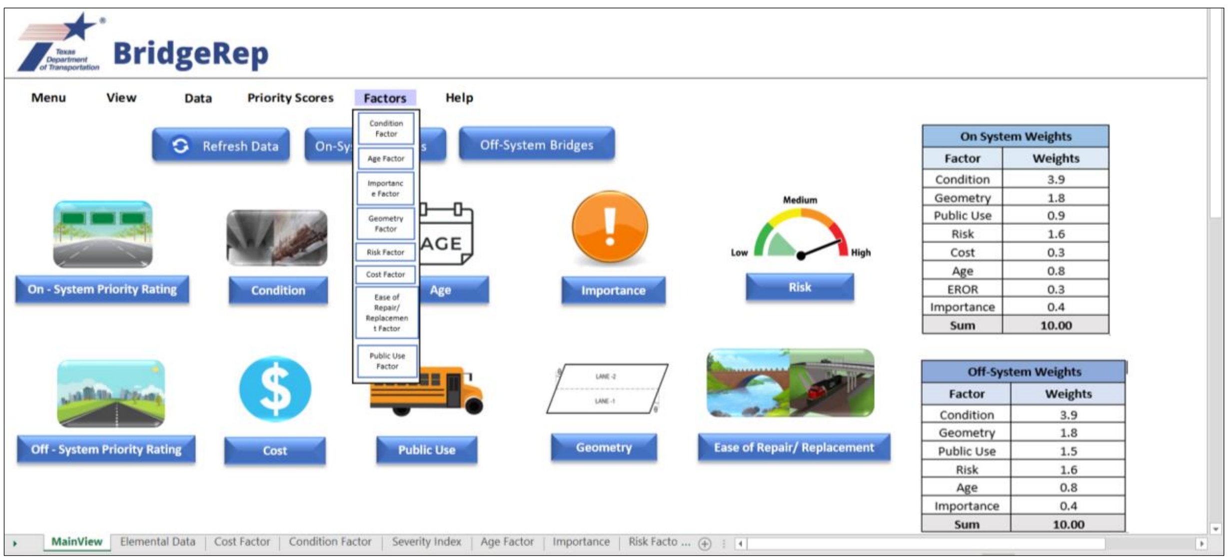


Figure 5-2: BridgeRep Main View Menu Features

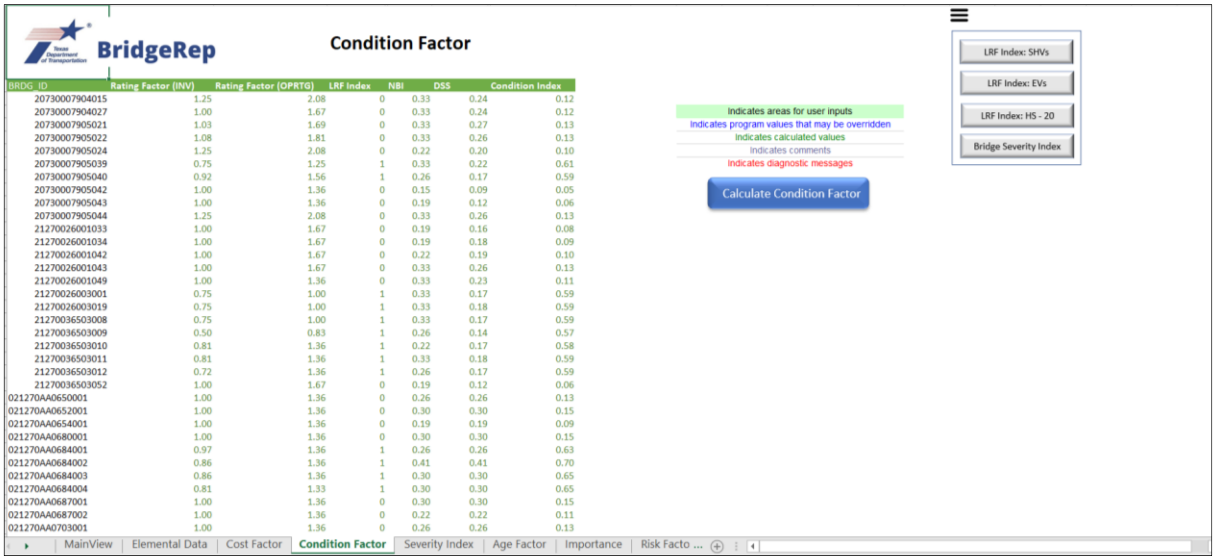


Figure 5-3: Condition Factor Dropdown Menu

Figure 5-4: Age Factor Dropdown Menu and

BridgeRep Ease of Repair/Replacement

Component Damaged	Relative Weights (User Input)	FEAT_INTSECT	Features Crossed	Feature Index	CULV_COND_RTNG
Superstructure	0.24	BARTON CREEK	Waterway	0.67	N
Substructure	0.24	BARTON CREEK	Waterway	0.67	N
Decks & Slabs	0.24	BARTON CREEK	Waterway	0.67	N
Culvert	0.24	BARTON CREEK	Waterway	0.67	N
Bearings	0.1	SALT CREEK	Waterway	0.67	N
Joints	0.08	LITTLE SUNDAY CREEK	Waterway	0.67	N
Railings	0.05	BARTON CREEK	Waterway	0.67	N
Wearing Surfaces & Protective Coatings & Concrete R	0.03	SALT CREEK	Waterway	0.67	N
Approach Slabs	0.02	BARTON CREEK	Waterway	0.67	N
		LITTLE SUNDAY CREEK	Waterway	0.67	N
		LOST CREEK	Waterway	0.67	N
		LOST CREEK	Waterway	0.67	N
		LITTLE SUNDAY CREEK	Waterway	0.67	N
		TURKEY CREEK	Waterway	0.67	N
		FLAT CREEK	Waterway	0.67	
		JONES CREEK	Waterway	0.67	
		JONES CREEK	Waterway	0.67	
		CARROLL CREEK	Waterway	0.67	N

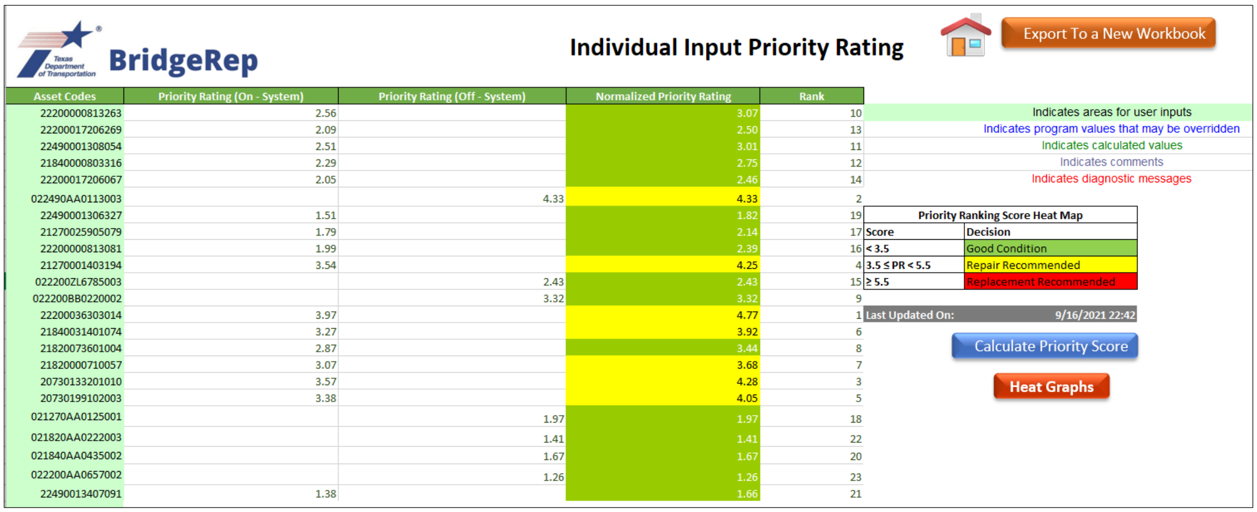
Figure 5-5: Ease of Repair and Replacement Factor User Input Options

Capabilities of BridgeRep:

- Provides a user-friendly platform including smart button animations to navigate through the software.
- Embedded with robust algorithms to calculate index values and priority rating scores for Off-System and On-System bridges based on the elemental inspection and NBI condition ratings.
- Updates the NBI data from the TxDOT Open Data Portal and Elemental Data from AssetWise.
- Produces heat graphs for appropriate repair/replacement decisions.
- Gives access to reference data and formulae for each factor.
- Provides access to the User Manual for both regular users and administrative purposes.

BridgeRep Final Scoring and Ranking

Figure 5-6 shows an individual input priority rating for both on-system and off-system bridges. Users can export the results to a new workbook after generating priority scores for any number of bridges. In the new workbook, the User can add rows and columns as needed and produce any new calculations as needed.



BridgeRep

Individual Input Priority Rating

Export To a New Workbook

Asset Codes	Priority Rating (On - System)	Priority Rating (Off - System)	Normalized Priority Rating	Rank
22200000813263	2.56		3.07	10
22200017206269	2.09		2.50	13
22490001308054	2.51		3.01	11
21840000803316	2.29		2.75	12
22200017206067	2.05		2.46	14
022490AA0113003		4.33	4.33	2
22490001306327	1.51		1.82	19
21270025905079	1.79		2.14	17
22200000813081	1.99		2.39	16
21270001403194	3.54		4.25	4
022200ZL6785003		2.43	2.43	15
022200BB0220002		3.32	3.32	9
22200036303014	3.97		4.77	1
21840031401074	3.27		3.92	6
21820073601004	2.87		3.44	8
21820000710057	3.07		3.68	7
20730133201010	3.57		4.28	3
20730199102003	3.38		4.05	5
021270AA0125001		1.97	1.97	18
021820AA0222003		1.41	1.41	22
021840AA0435002		1.67	1.67	20
022200AA0657002		1.26	1.26	23
22490013407091	1.38		1.66	21

Indicates areas for user inputs
Indicates program values that may be overridden
Indicates calculated values
Indicates comments
Indicates diagnostic messages

Priority Ranking Score Heat Map	
Score	Decision
< 3.5	Good Condition
3.5 ≤ PR < 5.5	Repair Recommended
≥ 5.5	Replacement Recommended

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Calculate Priority Score

Heat Graphs

Figure 5-6: BridgeRep Individual Input Priority Rating

BridgeRep User Manual and Tutorial Video

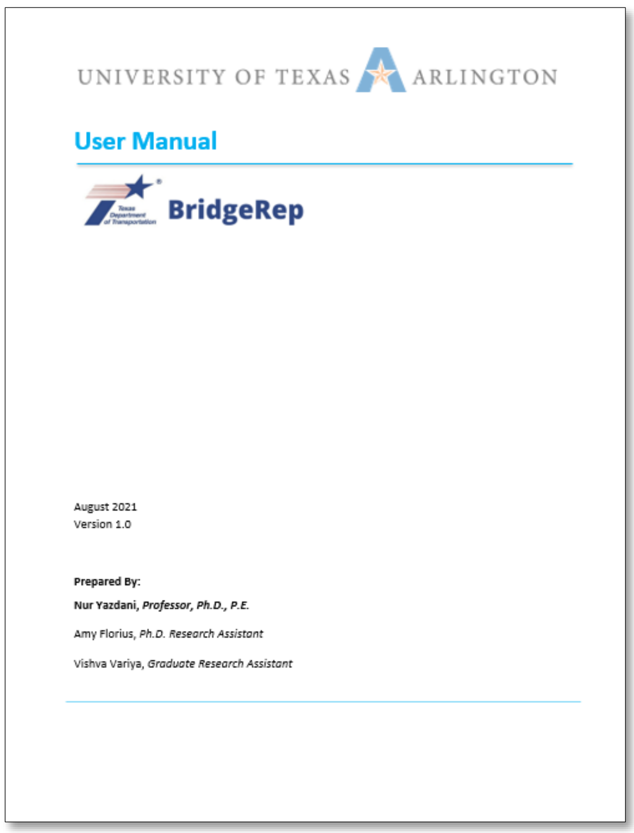
Regular User Manual

- ➢ Provides guidance on installing the add-ons required for BridgeRep to run smoothly (interface shown in Figure 5-7)
- ➢ Provides step-by-step instructions on how to navigate the decision tool
- ➢ Describes the purpose of each smart button
- ➢ Provides guidance on the location of each formula and the purpose of the formula embedded within the macro

- Describes the data dumping process in detail; including which elements are excluded from the NBI data list when pulling the data from the Open Data Portal (eg. any bridges under construction/closed)

Administrative User Manual

- Specifically for Administrative staff members
- Includes the description of each code and highlights the formulas within


UNIVERSITY OF TEXAS ARLINGTON

User Manual

BridgeRep

August 2021
Version 1.0

Prepared By:
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Figure 5-7: BridgeRep User Manual Interface

CHAPTER 6

Conclusions

- The SRS was investigated and incompetences with the model were identified. Improvements were made to the model by incorporating new factors which were critical to the decision-making process.
- A statewide study was conducted to investigate whether the SRS was being used for repair/replacement decisions. It was found that 66% used the SRS, 8% did not use it, 8% their own in-house priority tools recommended by the MAP-21 legislature, and 18% unconfirmed.
- A decision tool for bridge repair/replacement was developed incorporating eight factors for on-system bridges and six factors for off-system bridges. The on-system factors include condition, cost, risk, EROR, importance, public use, age, and geometry. The off-system factors include condition, risk, importance, public use, age, and geometry. Each factor is calculated on a scale of zero to one and the total score for the on- and off-system PR is 10.
- To calculate the priority scores, a weighting factor was assigned to all factors and subfactors. A statewide study was conducted to investigate the weights used for similar factors considered in the decision tool to assign appropriate weighting factors. After, the AHP was used to obtain analytic weights of the factors. The weights were then provided to TxDOT for input. Feedback was received from a panel of 15 expert engineers at TxDOT for the final factor weights.
- TxDOT has been collecting ELID but was not using it to calculate numerical scores to determine the need for bridge repair/replacement. They were incorporated into the decision tool through the development of bridge SI. The bridge SI is a numeric representation of the

condition of the bridge using ELID. It is calculated by first determining the local SI which is the severity of an individual bridge element. The final bridge SI value is calculated by summing the product of the local SI and the relative element weight, then dividing by the sum of the importance weights.

- The condition factor for on-system bridges utilizes ELID to obtain a better representation of the condition of the structure. 50% of the condition factor is based on the physical condition of the bridge which is measured by the DSS score. ELID is combined with NBI condition ratings to calculate the DSS score. Since ELID quantifies the extent of damage in bridges, combining them with the established NBI condition ratings gave a better idea of the actual condition of the bridge.
- To facilitate the repair/replacement decisions, thresholds were set for good condition, repair recommendations, and replacement recommendations. Bridges with PRs below 2.5 were considered to be in good condition. Bridges with PRs between 2.5 and 5.5 were recommended for repair, and those with PRs greater than 5.5 were recommended for replacement.
- Bridge elemental data and NBI condition ratings were also useful to assist in bridge decisions. NBI condition ratings of 7 and above were considered good condition, 5 and 6, repair recommended and 4 and below, replacement was recommended. Using the local SI, bridges with values less than 0.33 were considered to be good condition. Local SI values between 0.33 and 0.67 were considered for repair, and values greater than 0.67 were considered for replacement.
- Heat graphs were developed using three colors to assist with the decision-making effort. Green represented good condition, yellow repair, and red, replace.

- An EXCEL-based decision tool (BridgeRep) was developed to automate PR and index score calculations. BridgeRep is fully equipped with smart buttons creating a user-friendly platform. The software contains different spreadsheets for the various factors with hovering features for the drop-down menus and refence data attached as part of the menu options. BridgeRep has the capability of updating with the latest bridge inspection data and can be used for any bridge database.

Future Research

- The decision tool factors can be extended to include socio-economic effects. A vital aspect of infrastructural decision-making may involve considering the impact of the community and economy. Consequently, including socio-economic impacts into a decision tool for bridge repair and replacement will result in a more robust and inclusive outcome.
- For effective bridge maintenance and preservation, bridges should be evaluated considering their entire life cycle. Therefore life-cycle cost analyses, benefit-cost analyses, and deterioration modeling can be incorporated into the tool to maintain good bridges in a state-of-good-repair.
- The weights assigned to the factors of the decision tool can be re-evaluated using a larger pool of expert engineers from various DOTs. This would provide a stronger basis for the factor weights.
- Data from government web sources such as TxDOT, National Oceanic and Atmospheric Administration, Federal Emergency Management Agency (FEMA), and other government agencies can be used to incorporate flood map data from FEMA. It can be used to depict the flood zones which can indicate high-risk areas.
- Fire impact on bridges can be considered in future models.

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APPENDIX A

Cost Analysis

Cost Analysis

Reinforced Concrete

Deck				
	Feasible Action	**Unit**	**Cost of Repair**	**Cost of Replacement**
Delamination/Spall/Patched Area (1080), Exposed Rebar (1090), Abrasion/Wear (PSC/RC) (1190), Damage (7000)	CONC STR REPAIR(DECK REP(PART DEPTH))	SF	$56.20	
	CONC STR REPAIR(RAPID DECK REP(PRT DPT)	SF	$141.22	
	CONC STR REPAIR(DECK REP (FULL DEPTH))	SF	$166.03	
	CONC STR REPR(RAPID DECK REP(FULL DPT))	SF	$267.76	
Cracking (RC) (1130)	CONC CRCK REPR(DISCRETE)(ROUT AND SEAL)	LF	$39.91	
	CNC CRACK REPAIR (DISCRETE)(GRAVITY)	LF	$35.00	
	CNC CRACK REPAIR (DISCRETE)(INJECT)	LF	$60.45	
Abrasion/Wear (PSC/RC) (1190)	MULTI-LAYER POLYMER OVERLAY	SY	$29.00	
Settlement (4000)	COMPACTION GROUTING	CF	$33.00	
Scour (6000)	RIPRAP (CONC)(4 IN)	CY	$544.64	
Reinforced Concrete Top Flange				
	Feasible Action	**Unit**	**Cost of Repair**	**Cost of Replacement**
Damage (7000)	CONCRETE BEAM REPAIR	EA	$12,000.00	
	CONCRETE BEAM REPAIR (CFRP)	EA	$16,000.00	
Reinforced Concrete Slab				

Damage (7000)	CONC STR REPAIR(DECK REP(PART DEPTH))	SF	$56.20	
	CONC STR REPAIR(RAPID DECK REP(PRT DPT)	SF	$141.22	
	CONC STR REPAIR(DECK REP (FULL DEPTH))	SF	$166.03	
	CONC STR REPR(RAPID DECK REP(FULL DPT))	SF	$267.76	
	Culvert			
	Feasible Action	**Unit**	**Cost of Repair**	**Cost of Replacement**
Scour (6000)	RIPRAP (CONC)(4 IN)	CY		
Damage (7000)	CONC BOX CULV (3 FT X 2 FT)	LF		
	CONC BOX CULV (5 FT X 2 FT)	LF		
	CONC BOX CULV (5 FT X 3 FT)	LF		
	CONC BOX CULV (7 FT X 7 FT)	LF		
	CONC BOX CULV (8 FT X 4 FT)	LF		
	CONC BOX CULV (10 FT X 8 FT)(EXTEND)	LF		
	CONCRETE BOX CULVERT(9FT X 10FT) EXTEND	LF		
Substructure				
Reinforced Concrete Column				
Scour (6000)	RIPRAP (CONC)(4 IN)	CY		
Damage (7000)	CONC STR REPR(REMOVE AND REPL COLUMN)	CY		
Reinforced Concrete Pier Wall				
Scour (6000)	RIPRAP (CONC)(4 IN)	CY		
Reinforced Concrete Abutment				
Scour (6000)	RIPRAP (CONC)(4 IN)	CY		
Damage (7000)	CONC STR REPR(REMOV AND REPL WINGWALL)	CY		

Reinforced Concrete Pile Cap/Footing				
Scour (6000)	RIPRAP (CONC)(4 IN)	CY		
Reinforced Concrete Pile				
Scour (6000)	RIPRAP (CONC)(4 IN)	CY		
Damage (7000)				
	REMOVE/REPLACE 14 PILE DOLPHIN	EA		
	REMOVE/REPLACE 19 PILE DOLPHIN	EA		
	REMOVE/REPLACE 23 PILE DOLPHIN	EA		
	REPL MONOPILE CNC TWR PAD 24" LAN 1,4,6	EA		
	REPL MOORNG RING 60" MONOPILE ANY LAN	EA		
	REPL MONOPILE 60" D X 120' L	EA		
Reinforced Concrete Cap				
Damage (7000)	CONC STR REPR(REMOVE AND REPLACE CAP)	CY	$8,600.00	
Reinforced Concrete Approach Slab				
Damage (7000)	FULL-DPTH REP(BR APPROACH SLAB)(9"-13")	SY	$416.08	
Reinforced Concrete Bridge Rail				
Damage (7000)	CONC RAIL REPAIR(REMOVE AND REPL RAIL)	LF		$152.52
	CONCRETE POST REPAIR	EA	$275.35	
	CONCRETE RAIL REPAIR (IN-KIND)	LF	$456.48	
	CONCRETE RAIL REPAIR (MISC)	LF	$71.43	
	CONCRETE RAIL REPAIR (TYPE 501)	LF	$520.00	
	CONCRETE RAIL REPAIR (TYPE 551)	LF	$92.50	
	CONCRETE RAIL REPLACEMENT (TYPE 201)	LF		$800.00

Prestressed Concrete

Deck				
	Feasible Action	**Unit**	**Cost of Repair**	**Cost of Replacement**
Delamination/Spall/Patched Area (1080), Exposed Rebar (1090), Abrasion/Wear (PSC/RC) (1190), Damage (7000), Distortion (1900)	CONC STR REPAIR(DECK REP(PART DEPTH))	SF	$56.20	
	CONC STR REPAIR(RAPID DECK REP(PRT DPT)	SF	$141.22	
	CONC STR REPAIR(DECK REP (FULL DEPTH))	SF	$166.03	
	CONC STR REPR(RAPID DECK REP(FULL DPT))	SF	$267.76	
Efflorescence/Rust staining (1120)				
Cracking (PSC) (1110)	CONC CRCK REPR(DISCRETE)(ROUT AND SEAL)	LF	$39.91	
	CNC CRACK REPAIR (DISCRETE)(GRAVITY)	LF	$35.00	
	CNC CRACK REPAIR (DISCRETE)(INJECT)	LF	$60.45	
Abrasion/Wear (PSC/RC) (1190)	MULTI-LAYER POLYMER OVERLAY	SY	$29.00	
	CONC STR REPAIR(DECK REP(PART DEPTH))	SF	$56.20	
	CONC STR REPAIR(RAPID DECK REP(PRT DPT)	SF	$141.22	
	CONC STR REPAIR(DECK REP (FULL DEPTH))	SF	$166.03	
Distortion (1900)	CONC STR REPR(RAPID DECK REP(FULL DPT))	SF	$267.76	
Settlement (4000)	REMOVE/REPLACE 19 PILE DOLPHIN	EA	$33.00	
Superstructure				
Damage (7000)	CONCRETE BEAM REPAIR	EA	$9,532.26	

	CONCRETE BEAM REPAIR (CFRP)	EA	$8,588.89	
	CONCRETE BEAM REP(STRAND SPLICE & CFRP)	EA	$12,564.29	
	CONCRETE BEAM REP (STRAND SPLICE)	EA	$6,775.00	
PSC Open Girder/Beam				
Damage (7000)	CONCRETE BEAM REPAIR	EA	$9,532.26	
	CONCRETE BEAM REPAIR (CFRP)	EA	$8,588.89	
	CONCRETE BEAM REP(STRAND SPLICE & CFRP)	EA	$12,564.29	
	CONCRETE BEAM REP (STRAND SPLICE)	EA	$6,775.00	
PSC Floor Beam				
Damage (7000)	CONCRETE BEAM REPAIR	EA	$9,532.26	
	CONCRETE BEAM REPAIR (CFRP)	EA	$8,588.89	
	CONCRETE BEAM REP(STRAND SPLICE & CFRP)	EA	$12,564.29	
	CONCRETE BEAM REP (STRAND SPLICE)	EA	$6,775.00	

Steel

Steel Deck with Open Grid				
	Feasible Action	**Unit**	**Cost of Repair**	**Cost of Replacement**
Corrosion (1000)				
Cracking (1010)	REPAIR PROP-WELDING OF CRACKS	EA	$3,116.00	
Connection (1020)	WELDING AND FITTING	HR	$63.95	
Distortion (1900)	REP STL BRIDGE MEMBER(STRAIGHTEN MEMB)	EA	$38,750.00	

Settlement (4000)				
Scour (6000)	RIPRAP (CONC)(4 IN)	CY	$544.64	
Damage (7000)				
Steel Truss				
Damage (7000)	REP STL BRIDGE MEMBER (TRUSS VERTICAL)	EA	$20,000.00	
	REP STL BRIDGE MEMBER(TRUSS SWAY BRACE)	EA	$35,000.00	
	REP STL BRDG MEMB (TRUSS PORTAL BRACE)	EA	$58,000.00	
Steel Floor Beam				
Damage (7000)	REP STL BRIDGE MEMBER (BEAM)	EA	$6,000.00	

APPENDIX B

TxDOT Questionnaire

TxDOT Questionnaire

The University of Texas at Arlington

Department of Civil Engineering

TxDOT Decision Tool for Bridge Repair and Replacement

Project Manager: Dr. Nur Yazdani, P.E., Professor

Ph.D. Research Assistant: Amy Florius

This questionnaire is designed to gather the opinion of TxDOT Fort Worth District Engineers on the weights of the Priority Rating main factors for a bridge repair/replacement prioritization decision tool. Elemental data will also be used to prioritize the bridges, therefore options for scoring individual groups of bridge elements are also provided for expert opinion inputs.

Instructions: Insert your opinion weights along the in the box provided, ensuring the total score of weights add up to 100. The analytic weights were calculated and are provided as a reference.

Name: ___________________________ **Position**:

____

Priority Rating = Priority Rating (1) = a(C) + b(CT) + c(R) +d(A) + f(E) + g(I) + h(G) + k(P)

C = Condition CT = Cost R = Risk A = Age E = Ease of Repair/Replacement

I = Historical Importance G = Geometry P = Public Use

WEIGHTS FOR PRIORITY RATING MAIN FACTORS

Factor	Sub-factors	Analytic Weights	Insert Opinion Weights
Condition	• Deck • Superstructure • Substructure • Culvert • Operating Rating • Inventory Rating	39	
Geometry	• Deck Geometry • Bridge Roadway Width • ADT • Waterway Adequacy • Underclearances • Min. vertical clearance over bridge deck	22	
Public use	• Intersecting Route ADT • Intersecting Route Bypass Detour Length • Bypass Detour Length	13	
Risk	• STRAHNET Highway Designation • Scour Critical Bridge	13	
Cost	• Cost of Repair/Replacement	6	
Age	Year Built	4	
Ease of Repair/Replacement	• Lanes on and Under structure • Component Damaged	2	
Historical Importance	-	2	
		INSERT SUM =	

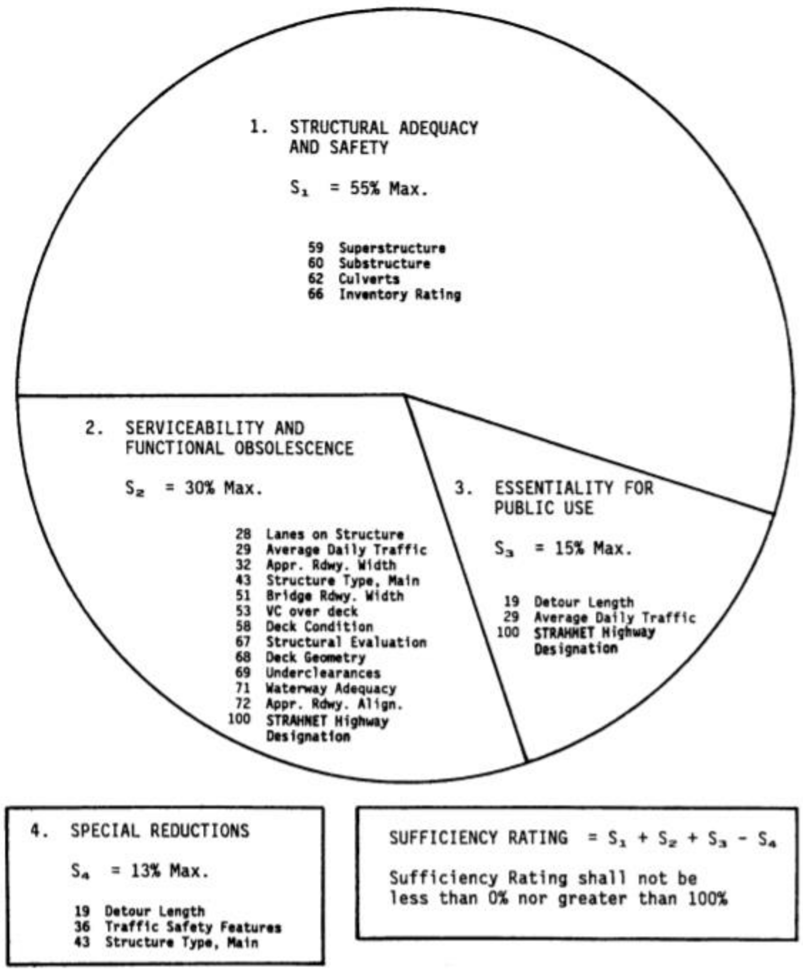
WEIGHTS FOR INDIVIDUAL GROUPS OF ELEMENTAL BRIDGE DATA

Element Group	Relative Weights	Insert Opinion Weights
Superstructure	24	
Substructure	24	
Decks and Slabs	24	
Bearings	11	
Joints	8	
Railings	5	
Wearing Surfaces, Protective Coatings, Concrete Reinforcing Steel Protective System	3	
Approach Slabs	2	
	INSERT SUM =	

APPENDIX C

FHWA & TxDOT SRS Formulas

FHWA Sufficiency Rating Formula



Sufficiency Rating Formula

1. Structural Adequacy and Safety (55% maximum)

a. Only the lowest rating code of Item 59, 60, or 62 applies.

If Item 59 (Superstructure Rating) or

Item 60 (Substructure Rating) is < 2 then A = 55%

= 3 A = 40%

= 4 A = 25%

= 5 A = 10%

If Item 59 and Item 60 = N and

Item 62 (Culvert Rating) is < 2 then A = 55%

= 3 A = 40%

= 4 A = 25%

= 5 A = 10%

b. Reduction for Load Capacity:

Calculate using the following formulas where

IR is the Inventory Rating (MS Loading) in tons:

B = (32.4 - IR)1.5 x 0.3254

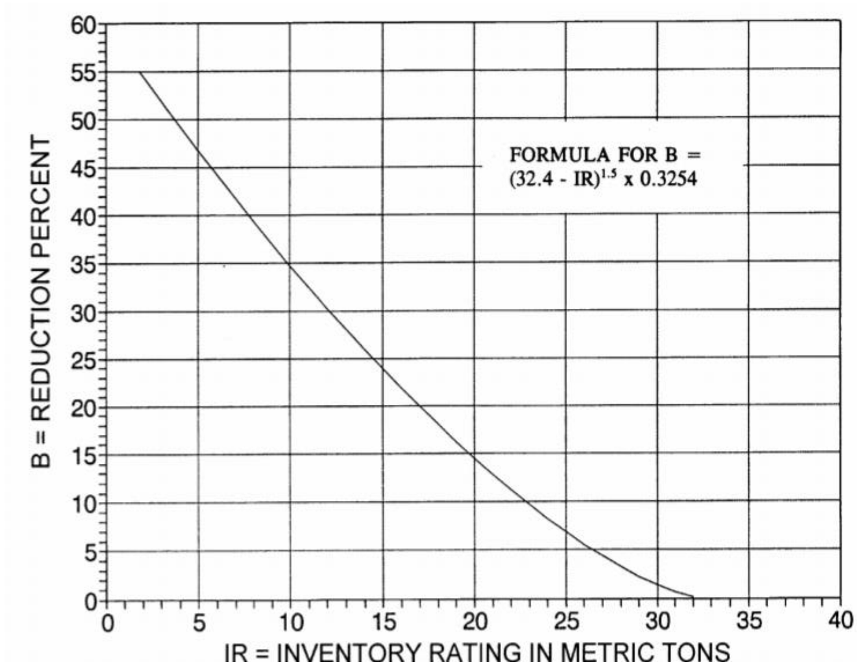
or

If (32.4 - IR) < 0, then B = 0

"B" shall not be less than 0% nor greater than 55%.

S1 = 55 - (A + B)

S1 shall not be less than 0% nor greater than 55%.



Serviceability and Functional Obsolescence (30% maximum)

a. Rating Reductions (13% maximum)

If #58 (Deck Condition) is < 3 then A = 5%

= 4 A = 3%

= 5 A = 1%

If #67 (Structural Evaluation) is < 3 then B = 4%

= 4 B = 2%

= 5 B = 1%

If #68 (Deck Geometry) is < 3 then C = 4%

= 4 C = 2%

= 5 C = 1%

If #69 (Underclearances) is < 3 then D = 4%

= 4 D = 2%

= 5 D = 1%

If #71 (Waterway Adequacy) is < 3 then E = 4%

= 4 E = 2%

= 5 E = 1%

If #72 (Approach Road Alignment) is < 3 then F = 4%

= 4 F = 2%

= 5 F = 1%

J = (A + B + C + D + E + F)

J shall not be less than 0% nor greater than 13%.

b. Width of Roadway Insufficiency (15% maximum)

Use the sections that apply:

(1) applies to all bridges;

(2) applies to 1-lane bridges only;

(3) applies to 2 or more lane bridges;

(4) applies to all except 1-lane bridges.

Also determine X and Y:

X (ADT/Lane) = Item 29 (ADT)

first 2 digits of #28 (Lanes)

Y (Width/Lane)* = Item 51 (Bridge Rdwy. Width)

first 2 digits of #28 (Lanes)

*A value of 10.9 Meters will be substituted when item 51 is coded 0000

or not numeric.

Use when the last 2 digits of #43 (Structure Type) are

not equal to 19 (Culvert):

If(#51 + 0.6 meters) < #32 (Approach Roadway Width) G = 5%

(2) For 1-lane bridges only, use the Figure or the following:

If the first 2 digits of #28 (Lanes) are equal to 01 and

Y < 4.3 then H = 15%

Y > 4.3 < 5.5 H =

Y > 5.5 H = 0%

(3) For 2 or more lane bridges. If these limits apply,

do not continue on to (4) as no lane width reductions

are allowed.

If the first 2 digits of #28 = 02 and Y > 4.9, H = 0%

If the first 2 digits of #28 = 03 and Y > 4.6, H = 0%

If the first 2 digits of #28 = 04 and Y > 4.3, H = 0%

If the first 2 digits of #28 > 05 and Y > 3.7 H = 0%

(4) For all except 1-lane bridges, use the Figure or the following:

If Y < 2.7 and X > 50 then H = 15%

Y < 2.7 and X < 50 H = 7.5%

Y > 2.7 and X < 50 H = 0%

If X > 50 but < 125 and

Y < 3.0 then H = 15%

Y > 3.0 < 4.0 H = 15(4-Y)%

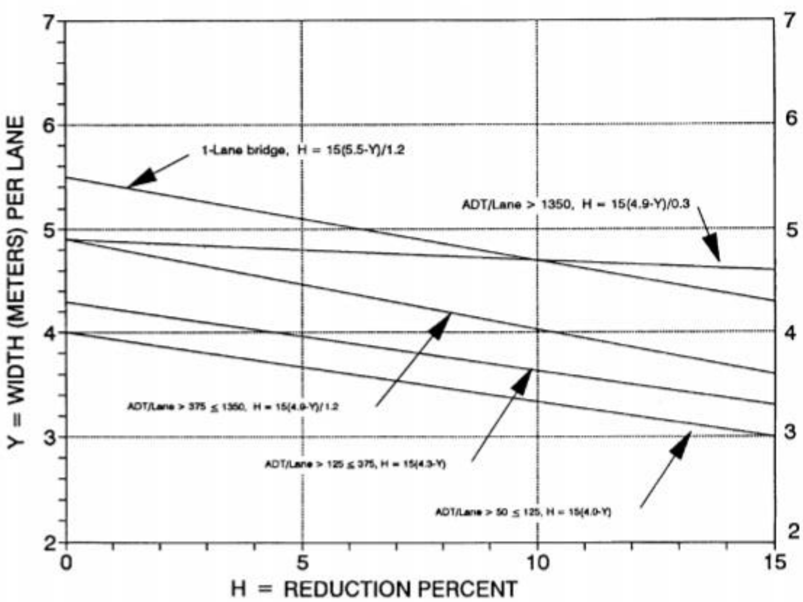
Y > 4.0 H = 0%

If X > 125 but < 375 and

Y < 3.4 then H = 15%

Y > 3.4 < 4.3 H = 15(4.3-Y)%

Y > 4.3 H = 0



If X > 375 but < 1350 and

Y < 3.7 then H = 15%

Y > 3.7 < 4.9 H =

Y > 4.9 H = 0%

If X > 1350 and

Y < 4.6 then H = 15%

Y > 4.6 < 4.9 H =

Y > 4.9 H = 0%

G + H shall not be less than 0% nor greater than 15%.

c. Vertical Clearance Insufficiency - (2% maximum)

If #100 (STRAHNET Highway Designation) > 0 and

#53 (VC over Deck) > 4.87 then I = 0%

#53 < 4.87 I = 2%

If #100 = O and

#53 > 4.26 then I = 0%

#53 < 4.26 I = 2%

S_2 = 30 - [J + (G + H) + I]

S_2 shall not be less than 0% nor greater than 30%.

3. Essentiality for Public Use (15% maximum)

a. Determine:

$K = \frac{S_1 + S_2}{85}$

b. Calculate:

A =

"A" shall not be less than 0% nor greater than 15%.

c. STRAHNET Highway Designation:

If #100 is > 0 then B = 2%

If #100 = 0 then B = 0%

S3 = 15 - (A + B)

S3 shall not be less than 0% nor greater than 15%.

4. Special Reductions (Use only when S1 + S2 + S3 > 50)

a. Detour Length Reduction, use the Figure or the following:

A = (#19)4 x (7.9 x 10-9)

"A" shall not be less than 0% nor greater than 5%.

b. If the 2nd and 3rd digits of #43 (Structure Type, Main)

are equal to 10, 12, 13, 14, 15, 16, or 17; then

B = 5%

c. If 2 digits of #36 (Traffic Safety Features) = 0 C = 1%

If 3 digits of #36 = 0 C = 2%

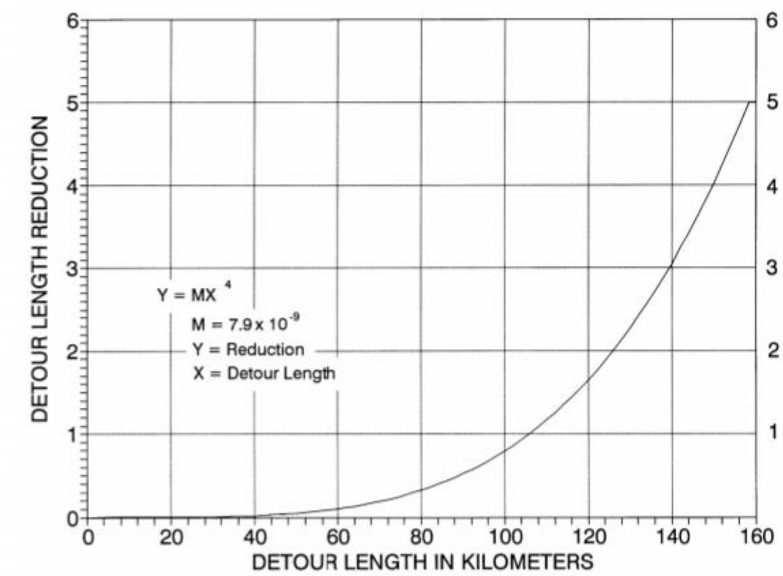
If 4 digits of #36 = 0 C = 3%

S4 = A + B + C

S4 shall not be less than 0% nor greater than 13%.

Sufficiency Rating = S1 + S2 + S3 - S4

The Rating shall not be less than 0% nor greater than 100%.



TxDOT Sufficiency Rating Formula

S1 is the Structural Adequacy and Safety (55 maximum, 0 minimum) calculated by the equation:

a. A is the Reduction for Deterioration (not to exceed 55 or be less than 0) based on the lowest value of Item 59 (Superstructure Rating) or lowest value of Item 60 (Substructure Rating):

if < 2, then A = 55

if = 3, then A = 40

if = 4, then A = 25

if = 5, then A = 10

if > 6, then A = 0

if = N, then A = 0

b. I is the Reduction for Load Capacity (not to exceed 55 or be less than 0) calculated by the equation and table:

S = S1 + S2 + S3 + S4

S1 = 55 – □A + I□

$I = 0.2778(36 – AIT)^{1.5}$

AIT is the Adjusted Inventory Tonnage, calculated by the following table of multipliers based on Item 66 (Inventory Rating):

1st digit of Item 66 is...	AIT = 2nd and 3rd digits of Item 66 multiplied by…
1	1.56
2	1.00
3	1.56
4	1.00
5	1.21
6	1.21
9	1.00

S2 = the Serviceability and Functional Obsolescence (30 maximum, 0 minimum) calculated by the equation: $S_2 = 30 – [J + (G + H) + I]$

a. J is a Rating Reduction (not to exceed 15) calculated by the following equation and tables:

J = A + B + C + D + E + F

If Item 58 (Deck Condition) is...	If Item 67 (Structural Evaluation) is...	If Item 68 (Deck Geometry) is...	If Item 69 (Underclearances) is...	If Item 71 (Waterway Adequacy) is...	If Item 72 (Approach Roadway Alignment) is...
≤ 3, then A = 5	≤ 3, then B = 4	≤ 3, then C = 4	≤ 3, then D = 4	≤ 3, then E = 4	≤ 3, then F = 4
= 4, then A = 3	= 4, then B = 2	= 4, then C = 2	= 4, then D = 2	= 4, then E = 2	= 4, then F = 2
= 5, then A = 1	= 5, then B = 1	= 5, then C = 1	= 5, then D = 1	= 5, then E = 1	= 5, then F = 1
≥ 6, then A = 0	≥ 6, then B = 0	≥ 6, then C = 0	≥ 6, then D = 0	≥ 6, then E = 0	≥ 6, then F = 0
= N, then A = 0	= N, then B = 0	= N, then C = 0	= N, then D = 0	= N, then E = 0	= N, then F = 0

b. (G + H) is a Width of Roadway Insufficiency (not to exceed 15) calculated by the following relationships where the values for X and Y are first found by the following equations:

Y = Item 51 (Roadway Width) ÷ First two digits of Item 28 (Lanes On)

If Item 5.6 = 1, 2 or 8, then;

X = Item 29 (Inventory Route ADT) ÷ First two digits of Item 28 (Lanes On)

Then use the following conditions of (1), (2), or (3) to obtain the values for G and H:

(1) For all bridges except culverts:	(2) For one-lane bridges (including one-lane culverts:	(3) For bridges with two or more lanes (including culverts):
• If Item 43.4 (Culvert Type) is blank or 0 and; • If Item 51 (Roadway Width) + 2 ft < Item 32 (Approach Roadway Width), then G = 5. • If Item 51 (Roadway Width) + 2 ft ≥ Item 32 (Approach Roadway Width), then G = 0.	• If the first two digits of Item 28 (Lanes On) = 01 and; • If Y < 14, then H = 15 • If 14 ≤ Y but < 18, then H = 3.75 (18 - Y). • If Y ≥ 18, then H = 0.	• If the first two digits of Item 28 (Lanes On) = 02 and Y ≥ 16, then H = 0. • If the first two digits of Item 28 (Lanes On) = 03 and Y ≥ 15, then H = 0. • If the first two digits of Item 28 (Lanes On) = 04 and Y ≥ 14, then H = 0. • If the first two digits of Item 28 (Lanes On) = 05 and Y ≥ 12, then H = 0. If any one of the preceding conditions is met, do not continue trying to determine H because no lane width reductions are necessary. Otherwise, determine H based on the following values for X and Y: • If X ≤ 50 and Y < 9, then H = 7.5 • If X ≤ 50 and Y ≥ 9, then H = 0. • If 50 < X ≤ 125 and Y < 10, then H = 15. • If 50 < X ≤ 125 and 10 ≤ Y < 13, then H = 5 (13 - Y) • If 50 < X ≤ 125 and Y ≥ 13, then H = 0 • If 125 < X ≤ 375 and Y < 11, then H = 15 • If 125 < X ≤ 375 and 11 ≤ Y < 14, then H = 5 (14 - Y) • If 125 < X ≤ 375 and Y ≥ 14, then H = 0 • If 375 < X ≤ 1350 and Y < 12, then H = 15 • If 375 < X ≤ 1350 and 12 ≤ Y < 16, then H = 3.75 (16 - Y) • If 375 < X ≤ 1350 and Y ≥ 16, then H = 0 • If X > 1350 and Y < 15, then H = 15 • If X > 1350 and 15 ≤ Y < 16, then H = 15 (16 - Y) • If X > 1350 and Y ≥ 16, then H = 0

c. I is a Vertical Clearance Insufficiency (not to exceed 2) set by the following:

If Item 100 (STRAHNET) > 0 and;

Item 53 (Min Vert Clearance Over Bridge Deck) > 1600 then I = 0

Item 53 (Min Vert Clearance Over Bridge Deck) < 1600 then I = 2

If Item 100 (STRAHNET) = 0 and;

Item 53 (Min Vert Clearance Over Bridge Deck) > 1400 then I = 0

Item 53 (Min Vert Clearance Over Bridge Deck) < 1400 then I = 2

3. S_3 is the Essentiality for Public Use (not to exceed 15 or be less than 0) calculated by the equation:

$S_3 = 15 – (P + M)$

a. P is the portion for Public Use.

First calculate K, which is a value based on the previously calculated S1 and S2:

$K = (S_1 + S_2) \div 85$

P = (Item 29* (ADT) x Item 19* (Detour Length) x 15) ÷ (200,000 x K)

*If Item 5.1 = 1 use Item 29 (ADT) and Item 19 (Detour Length)

*If Item 5.1 = 2 use Item 29A (Intersecting Route ADT) and Item 19A (Intersecting Route Detour Length)

b. M is the portion for Military Use.

If Item 100 (STRAHNET) > 0, then M = 2

If Item 100 (STRAHNET) = 0, then M = 0

4. S_4 is a Special Reduction used only when $(S_1 + S_2 + S_3) \geq 50$. Calculate S4 using the equation:

$S_4 = R + S + T$

a. R is a Detour Length Reduction (not to exceed 5) calculated by the equation:

R = [Item 19* (Detour Length)]^4 x (5.205 x 10^{-8})

*If Item 5.1 = 1 use Item 19 (Detour Length)

*If Item 5.1 = 2 use Item 19A (Intersecting Route Detour Length)

b. S is a Structure Type Reduction set by the following:

If the first digit of Item 43.1 (Main Span Type) is 7 or 8 or if the 2nd digit of Item 43.1 (Main Span Type) is 2, 3, 4, 5, 6, or 7, then S = 5.

Otherwise, S = 0

c. T is a Traffic Safety Feature reduction set by the following:

If 2 digits of Item 36 (Traffic Safety Features) = 0, then T = 1

If 3 digits of Item 36 (Traffic Safety Features) = 0, then T = 2

If 4 digits of Item 36 (Traffic Safety Features) = 0, then T = 3

APPENDIX D

Images of Test Bridges

Bridge #2:

Elevation Looking Southwest

Under Looking South

Roadway Under Looking East

Missing 20ft Tube Section on East Rail Bridge

Pothole of 1 sq ft on Deck Pavement

Spall on East Parapet

Broken Rail Posts on West Bridge Rail

Distressed Area on Asphalt Pavement

Missing 20 ft tube section on West bridge rail

Missing posts on West bridge rail

Northeast riprap heaving

Bridge: 22200000813263

Roadway Over Bridge - Looking Southwest

Elevation - Looking North

Superstructure - Looking Northeast

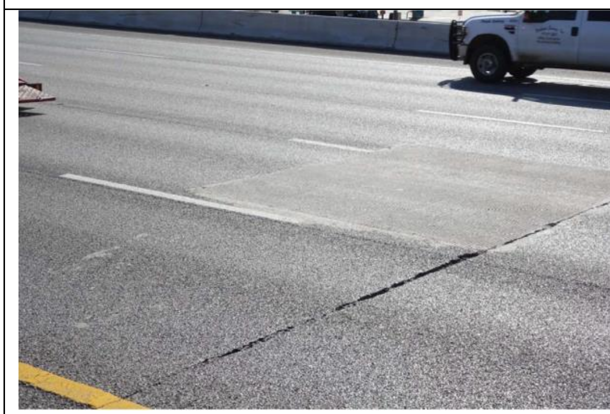
Roadway Under Bus 287 Sb – Looking Southeast

Spalled SE Bridge Rail

Span 1 From SW Looking Northeast

Minor Deterioration Along SW Abutment Joint

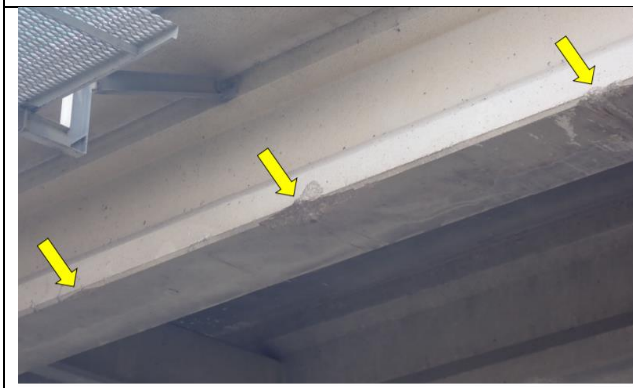
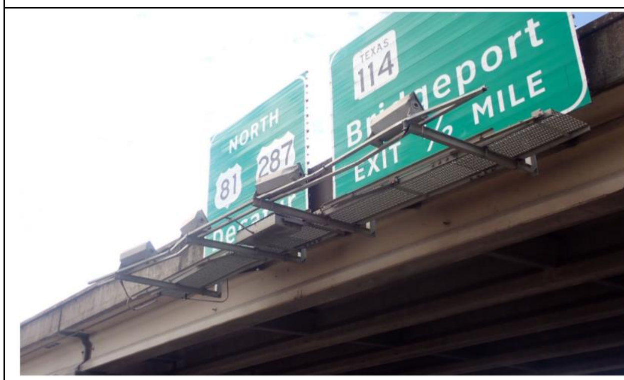
Looking Northwest

Bridge: 22200000813263	
 Full Depth Deck Repair NE Span Looking Southwest	 Cracked Diaphragm Weld NE End Span Looking North
 Deck Movement NE Span Looking Southeast	 Horizontal Column Crack Bent 2 From SW Looking Southwest

 Gap Between SW Riprap and Retaining Wall Looking West	

Bridge: **022490001308054**	
 Roadway View Looking South.	 East Bridge Elevation Looking Southwest.

 Underside Of Superstructure in Span 2 Looking North.	 Roadway (Us 81/287 Wb) Under View in Span 2 Looking West
 Large Patch in The Span 4 Deck Top Surface at Bent 4, Looking West. (Condition Rating: 7)	 Large Patch in The Span 5 Deck Top Surface at Abutment 6, Looking North. (Condition Rating: 7)

Bridge: **022490001308054**	
 Minor Overheight Impact Spalls of Beam 1 In Span 2, Looking Southwest. (Condition Rating: 6)	 Minor End Delamination/Spalls With Exposed Reinforcement Of Beam 2 in Span 4, Looking Northwest. (Condition Rating: 6)
 Damage To The Light Supports On The Sign Over The East Side Of Span 2, Looking Southwest.	 Minor Delamination Cracks And A Minor Spall On The South Face Of The Bent 4 Cap, Looking North. (Condition Rating: 6)
	

Moderate Spalls With Exposed Reinforcement In The Underside Of The Bent 5 Cap, Looking Southwest. (Condition Rating: 6)	Major Deformation Of The Northeast Corner Approach Guardfence Due To Impact, Looking Southwest. (Condition Rating: 6)

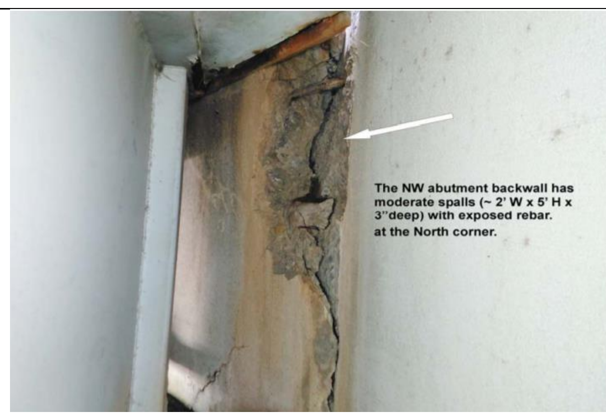
Bridge: **021840000803316**	
 Roadway Ih 20 Eb Looking Southeast	 Elevation Ih 30 Ebfr Looking Southwest
 Superstructure Looking Southeast	 IH 30 EBFR 16 FT 1 IN LOOKING EAST

SPALLED SE ABUTMENT CAP LOOKING SOUTH

Rusted Beam End At East Corner Looking East

Bridge: **021840000803316**

Closed Nw Abut. Joint Looking East



SPALLED NW ABUT. BACKWALL LOOKING WEST

IMPACT DAMAGE N. GUARDFENCE LOOKING NORTH

REPLACED SE APPROACH SLAB LOOKING NORTHEAST

Bridge: **022200017206067**

Roadway Over Bridge Looking North

Elevation Looking Southeast

Superstructure Looking South

Roadway Under Carey St. Looking West

 Pothole In Deck Span 2 Looking West	 East Concrete Bridge Rail Spall Looking North

Bridge: **022200017206067**	
 Tube Rail Damage Looking North	 Impact Crack & Spall E Railing At N End Looking Northwest

Spall @ Se Bridge Corner Looking Southwest

Overall Impact W. Exterior Beam W/ Tarp Looking Northeast

Overheight Impact Span 2 (Center) Looking South

Note: The West Exterior Beam Is Significantly Disorted With Detached Diaphragms. A Tarp Has Been Installed Around The Beam Over The Travel Lanes Below.

Gen. Beam Distortion & Tarp Looking South

Note: See Overall Impact Comment Above. The Exterior Beam Has A Hole In The Web Where Bottom Angle Of The Nw Int. Diaphragm Has Torn Loose.

Bridge: **022200017206067**	

 Closed W. Shoulder Looking South	 Damaged W. Bearing Bent 2 From North Looking South
 Damaged West Bearing & Beam Looking South	 Deck Spall & Hole In Web Looking South
 Beam Distortion & Detached Diaphragms Looking South	 Missing Cotter Pins Nw Abutment Looking North

Bridge: **022200017206067**	
	
W. Exterior Column Base Spall Looking North	Erosion At Nw Corner Embankment Looking Southwest

Bridge: **022490aa0113003**	
 Roadway View Looking East	 Side View Looking Southeast
 Superstructure View Looking West	 Stream Under Bridge Looking North
 Upstream Channel Looking North	 Downstream Channel Looking South

Bridge: **022490aa0113003**

Load Posting - West Approach Looking East

Load Posting - East Approach Looking West

Corroded Web Looking South

Note: Heavy Rust With Pitting And Flaking On Middle Steel Pile At West Abutment With Small Hole Through Web.

Bridge: **022490001306327**	
 Roadway View Looking Northwest.	 Northeast Bridge Elevation Looking West.
 Underside Of Superstructure In Span 2 Looking Northwest.	 Channel Under View Looking Northeast
 Upstream Channel Looking Northeast	 Downstream Channel Looking Southwest

 Hairline Map Cracks With Caving In The Deck Top Surface In Span 3, Looking Southwest. (Condition Rating: 6)	 Minor Spall In The Deck Top Surface Along The Bent 4 Joint, Looking Southwest. (Condition Rating: 6)
Bridge: **022490001306327**	
 24" Long By 8" Wide By 1" Deep Spall In The Northeast Bridge Railing In Span 4, Looking East. (Condition Rating: 7)	 Moderate Erosion Gullies In The Southeast Overbank In Span 3, Looking Northwest. (Condition Rating: 7)
 Exposed Column 5 Drilled Shaft At Bent 3 Due To Erosion, Looking North. (Condition Rating: 7)	 Exposed Column 3 Drilled Shaft At Bent 3 Due To Erosion, Looking Northwest. (Condition Rating: 7)

<table>
<tr><td>Bridge: 021270025905079</td><td></td></tr>
<tr><td>
Roadway View Us 67 Nb Looking East</td><td>
Elevation Up Rr Looking Northeast</td></tr>
<tr><td>
Superstructure Looking East</td><td>
Up Rr Looking Southeast</td></tr>
<tr><td>
Settlement Right Shoulder Looking South</td><td></td></tr>
</table>

Bridge: **022200000813081**	
 Roadway Over Bridge (Looking East)	 Elevation (Looking West)
 Superstructure (Looking West)	 Roadway Under Bridge - East Turnaround (Looking Southeast)
 Railroad Under Bridge (Looking Northwest)	 Roadway Under Bridge - West Turnaround (Looking Northwest)

Bridge: **022200000813081**	
 Asphalt Cracking At West Relief Joint (Looking Southeast)	 Asphalt Spalling Above West Abutment Joint (Looking Southeast)
 Spall In West Approach Slab At Southeast Corner (Looking Southwest)	 Spalling Along Base Of North Bridge Rail At West Abutment (Looking West)
 Settlement Of Rip Rap At East Abutment Cap (Looking South)	 Settlement Of Rip Rap At West Abutment Cap (Looking North)

Bridge: **022200000813081**	
 Missing Nut For Anchor Bolt On North Bearing At Bent 7 From West (Looking Southwest)	 South Diaphragm Has A Cracked Connection To Web Of Beam 4 From North Over East Abutment (Looking North)
 Spall With Exposed Steel On Deck Overhang At Northwest Corner (Looking Southwest)	 Horizontal Cracking In Column 2 From North At Bent 7 From West (Looking East)
	

Typical Horizontal Cracking On Columns At Bents 2 And 7 From West (Looking Southwest)	

Bridge: **021270001403194**	
 ROADWAY VIEW Looking North	 SIDE VIEW Looking Northwest
 SUPERSTRUCTURE Looking North	 ROADWAY UNDER BRIDGE IH 35W SB EXIT Looking Southeast

 PREVIOUS CONCRETE DECK REPAIRS Looking North	 MODERATE MAPPING CRACKS IN BOTTOM OF DECK Looking North

Bridge: **021270001403194**	
 SPALLS AT WEST OVERHANG SOFFIT Looking East	 SPALLS AND POTHOLES ALONG CONSTRUCTION JOINTS Looking West
	

SEVERAL REPAIR PATCHES ON TOP OF DECK Looking Southwest	IMPACT DAMAGE ON BOTTOM OF WEST EXTERIOR BEAM Looking North
 MODERATE FLAKING RUST AND PITTING ON STEEL BEAMS Looking North	 2' x 8' DELAMINATION ON BENT CAP 2 Looking Northeast

Bridge: **021270001403194**	
 SETTLED RIP-RAP AT SW CORNER Looking South	 WINGWALL UNDERMINING AT NW CORNER Looking East

<table>
<tr><td>Bridge: 022200ZL6785003</td><td></td></tr>
<tr><td>
ROADWAY VIEW Looking East</td><td>
SIDE VIEW Looking Northwest</td></tr>
<tr><td>
SUPERSTRUCTURE VIEW Looking East</td><td>
STREAM UNDER BRIDGE Looking Northwest</td></tr>
<tr><td>
UPSTREAM CHANNEL Looking Northwest</td><td>
DOWNSTREAM CHANNEL Looking Southeast</td></tr>
</table>

Bridge: **022200ZL6785003**	
 DAMAGED GUARDFENCE Looking Southeast	 SPALLED ASPHALT Looking Northwest
 CRACKED BEAM Looking West	 SPALLED WINGWALL Looking Southeast

Bridge: **022200BB0220002**	
	

ROADWAY VIEW Looking West	SIDE VIEW Looking Northeast
 SUPERSTRUCTURE VIEW Looking East	 STREAM UNDER BRIDGE Looking Northeast
 UPSTREAM CHANNEL Looking North	 DOWNSTREAM CHANNEL Looking South

Bridge: **022200BB0220002**	
	

LOAD POSTING - EAST APPROACH Looking West	LOAD POSTING - WEST APPROACH Looking East
 CRACKED T-BEAM Looking Northeas	 SPALLED T-BEAM Looking West
 SPALLED COLUMN Looking East	 UNDERMINED RIPRAP Looking Northeast
 EROSION Looking Southeast	

Bridge: **022200036303014**

ROADWAY OVER BRIDGE - SYLVANIA AVENUE SOUTHBOUND (LOOKING SOUTHWEST)

ROADWAY OVER BRIDGE - SYLVANIA AVENUE NORTHBOUND (LOOKING NORTH)

ELEVATION (LOOKING SOUTHWEST)

SUPERSTRUCTURE (LOOKING SOUTH)

ROADWAY UNDER BRIDGE - SH 121 NORTHBOUND (LOOKING EAST)

DETERIORATION OF NORTH RELIEF JOINT (LOOKING WEST)

Bridge: **022200036303014**	
 DAMAGED BEAM 8 FROM EAST AT SPAN 3 FROM SOUTH (LOOKING SOUTH)	 IMPACT DAMAGE TO EAST EXTERIOR BEAM IN SPAN 3 FROM SOUTH OVER SH 121 SB LANES (LOOKING SOUTH)
 IMPACT DAMAGE TO STREET SIGN ATTACHED TO WEST BRIDGE RAIL OVER SH 121 NB LANES (LOOKING NORTH)	 CLOSE UP OF DAMAGE TO EAST EXTERIOR BEAM IN SPAN 3 FROM SOUTH OVER SH 121 SB LANES (LOOKING SOUTHEAST)

 TWISTING OF BEAM 2 FROM EAST IN SPAN 3 FROM SOUTH (LOOKING SOUTH)	 MAP CRACKING ON ASPHALT SURFACE IN SOUTH SPAN (LOOKING SOUTHWEST)

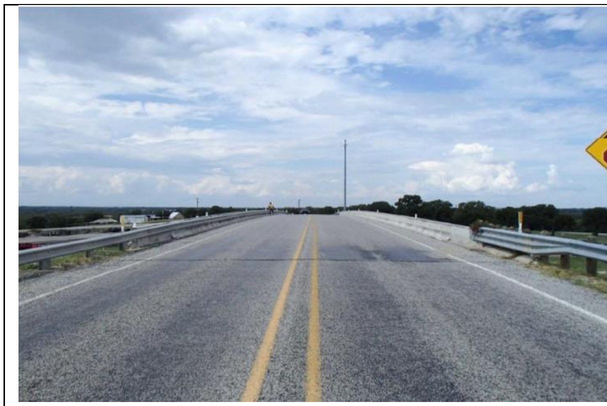
Bridge: **022200036303014**	
 MISSING ANCHOR BOLT AND NUT AT BEARING 11 FROM WEST AT NORTH ABUTMENT (LOOKING NORTH)	 MISSING ELECTRICAL BOX COVER ON BEAM 2 FROM WEST AT NORTH ABUTMENT (LOOKING EAST)

 PACK RUST BETWEEN BEAM END DIAPHRAGM AT SOUTH ABUTMENT (LOOKING SOUTHEAST)	 RUSTING OF STEEL MEMBERS AT SOUTH ABUTMENT (LOOKING SOUTHWEST)
 SPALLING ALONG NORTH ABUTMENT JOINT (LOOKING WEST)	 SPALLING ALONG SOUTH ABUTMENT JOINT (LOOKING EAST)

Bridge: **022200036303014**	
	

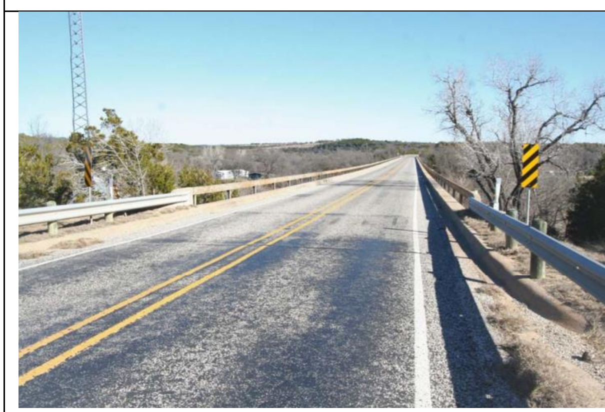
SPALLING AND DELAMINATION IN SOFFIT AT SOUTHWEST CORNER (LOOKING SOUTHWEST)	SPALLING WITH EXPOSED STEEL IN TOP DECK OF SPAN 3 FROM SOUTH (LOOKING WEST)
 SPALLING WITH EXPOSED STEEL IN NORTH BACKWALL NEAR BEARING 12 FROM WEST (LOOKING NORTHWEST)	 SPALL WITH EXPOSED STEEL IN DECK SOFFIT AT SOUTH SPAN (LOOKING SOUTHEAST)
 SPALL WITH EXPOSED STEEL IN WEST BRIDGE RAIL OVER BENT 2 FROM SOUTH (LOOKING NORTHWEST)	 TREE GROWING IN RIP RAP UNDER BRIDGE AT SOUTHEAST CORNER (LOOKING SOUTH)

Bridge: **021840031401074**	

 ROADWAY VIEW FM 1189 Looking North	 ELEVATION IH 20 Looking Southeast
 SUPERSTRUCTURE Looking South	 IH 20 WB UNDER Looking West
 IH 20 EB UNDER Looking East	 BEARING PEDESTAL SPALLS Looking South

EROSION REPAIR Looking Northeast

Bridge: **021820073601004**



ROADWAY OVER BRIDGE Looking North

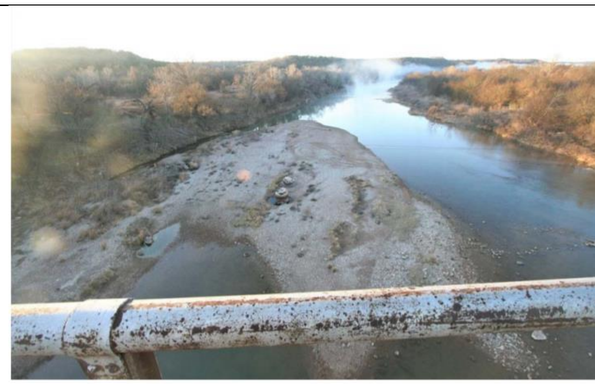
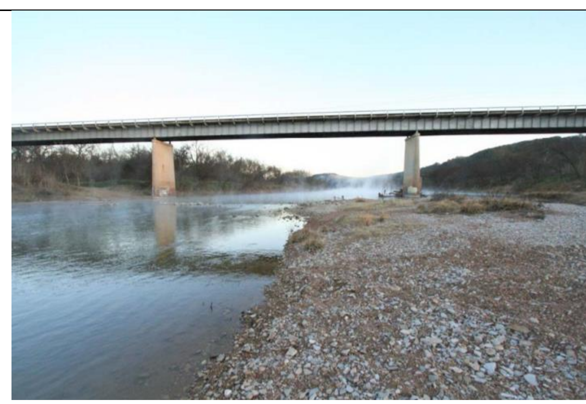
ELEVATION Looking Southwest

UPSTREAM VIEW FROM BRIDGE Looking West

DOWNSTREAM VIEW FROM BRIDGE Looking East

 SUPERSTRUCTURE Looking Northwest	 STREAM UNDER BRIDGE Looking West

Bridge: **021820073601004**	
 EROSION HOLE AT NE SHOULDER Looking Southwest	 RUSTED STEEL PILING AT NORTH ABUTMENT Looking North
 EROSION REPAIR AT NORTH ABUTMENT Looking Northwest	 SPALL AT EAST COLUMN BENT 4 Looking North

Bridge: **021820000710057**	
 ROADWAY OVER BRIDGE Looking West	 ELEVATION Looking Northwest
 UPSTREAM VIEW FROM BRIDGE Looking North	 DOWNSTREAM VIEW FROM BRIDGE Looking South
 SUPERSTRUCTURE Looking Northwest	 STREAM UNDER BRIDGE Looking North

Bridge: **021820000710057**	
 DAMAGED RAIL Looking West	 CONCRETE DECK AND CAP DETERIORATION Looking North
 DRIFT AT BENT 5 Looking Southwest	

Bridge: **020730133201010**	
 1 - Roadway looking Northwest (FM 1188)	 2 - Roadway looking Southeast (FM 1188)

3 - Elevation looking South

4 - Under looking Southeast

5 - Under looking Southeast

6 - Stream Under looking Southwest

Bridge: **020730133201010**

7 - Upstream looking Southwest

8 - Downstream looking Northeast

 9 - East corner wingwall is spalled at rail connection, 3 bolts completely loose (Looking Southwest)	

Bridge: **020730199102003**	

1 - Roadway looking Northwest (FM 2156)

2 - Roadway looking Southeast (FM 2156)

3 - Elevation looking North

4 - Under looking Southeast

5 - Stream Under looking Southwest

6 - Upstream looking Northeast

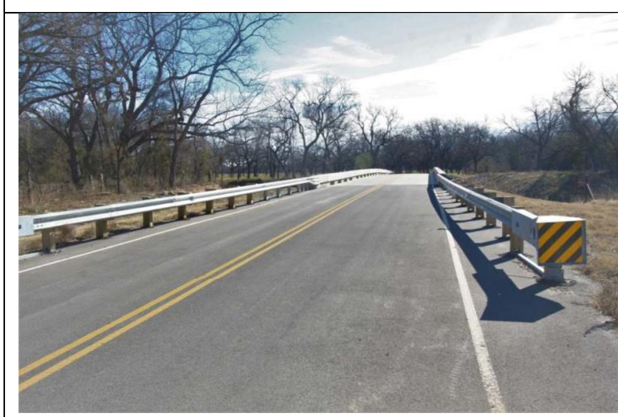
Bridge: **020730199102003**	
 7 - Downstream looking Southwest	 8 - Piles at bent 2 have rusting and flaking near water line (Looking South)
 9 - Erosion gullies at southeast channel bank (active erosion along channel bank) (Looking Southeast)	 10 - Southeast concrete riprap toe is exposed 30 inches (Looking Southeast)

Bridge: 021270AA0125001	
 1 - Roadway looking East (CR 915 - PCT. 2)	 2 - Roadway looking West (CR 915 - PCT. 2)
 3 - Elevation looking Northwest	 4 - Under looking West
	

5 - Stream Under looking North	6 - Upstream looking South

Bridge: 021270AA0125001	
 7 - Downstream looking North	 8 - East abutment steel plate backwall is undermined and material spilling through (TYP at west abutment) (Looking Northeast)
	

9 - East abutment center steel pile is has moderate rusting and flaking (TYP) (Looking North)	

Bridge: **021820AA0222003**	
 ROADWAY OVER BRIDGE Looking East	 ELEVATION Looking Northeast

UPSTREAM VIEW FROM BRIDGE
Looking South

DOWNSTREAM VIEW FROM BRIDGE
Looking North

SUPERSTRUCTURE Looking Southwest

STREAM UNDER BRIDGE Looking South

Bridge: **021840AA0435002**	

ROAD OVER LOOKING SE

ELEVATION LOOKING NORTH

Superstructure

Stream under looking NE

Upstream looking NE

Downstream looking SW

 NW channel bank under bridge has moderate erosion and is steep.	 Minor to moderate embankment erosion at south corner of bridge has exposed backside of steel wing wall.

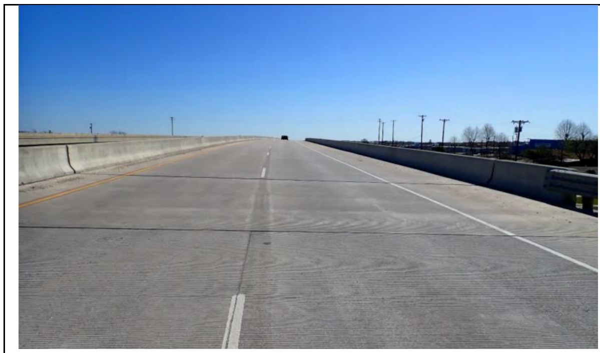
Bridge: **022200aa0657002**	
 Road over looking east	 Elevation looking nw
 Superstructure	 Stream under looking north

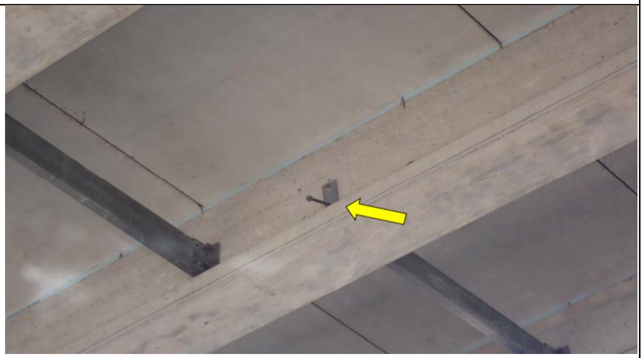
 Upstream looking south	 Downstream looking north

Bridge: **022200aa0657002**	
 Dirt and construction debris around girder bearing at east abutment.	 Significant erosion of east upstream bank ~150' from bridge.

 Timber bracing/forms left in place at east bent	

Bridge: **022490013407091**	

 Roadway view looking east.	 South bridge elevation looking northeast.
 Underside of superstructure in Span 1 looking east.	 Underside of superstructure in Span 2 looking east.
 Roadway (FM 730) under view in Span 2 looking south.	 Minor diagonal cracks with light efflorescence in the deck soffit at Bent 6, looking east. (Condition Rating: 8)

Bridge: **022490013407091**	
 Minor soot staining on the beams over the railroad tracks in Span 6, looking southwest. (Condition Rating: 8)	 Missing connection nut in the Diaphragm 2 connection to Beam 3 in Span 14, looking northwest. (Condition Rating: 7) Note bolt with missing nut is partially dislodged from the bolt hole
 Beam 4 bearing pad at Abutment 1 bulging slightly, looking west. (Condition Rating: 7)	

APPENDIX E

Hand Calculations

1. **Condition**
   0.5*DSS Index + 0.5*LRF Index

   DSS Index = $1 - \frac{DECK+SUPERSTRUCTURE+SUBSTRUCTURE}{27} = 1 - \frac{8+4+6}{27} = 0.333$

   LRF Index =

<table>
<tr><th>LRF Score</th><th colspan="2">Index Score Formula</th></tr>
<tr><td rowspan="4">Inventory Rating

Operating Rating</td><td>Criteria</td><td>Index Score</td></tr>
<tr><td>OR or IR < 3T</td><td rowspan="2">1</td></tr>
<tr><td>IR RF <1</td></tr>
<tr><td>IR ≥ 36 T</td><td>0</td></tr>
</table>

   NBI 064: Operating Rating: 60

   NBI 066: Inventory Rating: 36

   $\therefore LRF\ Index = 0$

   Condition Score = 0.5*DSS + 0.5*LRF = 0.5*0.333 + 0.5*0 = 0.167

2. Age Index

Bridge Age	**Index Score**
0 – 25 Years	0
26 - 50 Years	0.39
51 – 75 Years	0.63
76 – 100 Years	1

   NBI 027: Year Built: 1980

Age = 41 Years

$\therefore Age\ Index = 0.39$

3. Importance Index

Index scores will be based on historical importance and special bridges.

- If Historical significance Index > 0, and Special Bridge Index = 0, Importance Index = Historical Significance Index.
- If Historical importance > 0, and Special Bridge Index = 1, Importance Index = 1.
- If Historical significance Index = 0, and Special Bridge Index = 1, Importance Index = 1.

Historical Importance	
Code	**Index Score**
1	1
2	0.75
3	0.5
4	0.25
5	0

Code	Description
1	Bridge is on the National Register of Historic Places. (Listing provided by the Historic Preservation Office).
2	Bridge is eligible for the National Register of Historic Places. (Not used unless specifically instructed).
3	Bridge is at least 40 years old and meets one or more of the following qualifications: • Is a pin-connected or otherwise unique truss, a suspension bridge, an arch bridge, or is made of cast iron. • Demonstrates unique architectural or engineering design, or artistic embellishment such as cast iron or steel finials and fretwork, or elaborate concrete form work. • Is a "one of a kind" design.
4	Historical significance is not determinable at this time, but is at least 40 years old.
5	Bridge is not eligible for the National Register of Historic Places, or is not 40 years old.

S = Special Bridges

If the first digit of Item 43.1 (Main Span Type) is 7 or 8 or if the 2nd digit of Item 43.1 (Main Span Type) is 2, 3, 4, 5, 6, or 7, then S = 1. Otherwise, S = 0.

1st Digit	SPAN TYPE	2nd Digit	ROADWAY TYPE
1	Simple Span	1	Deck
2	Continuous	2	Through
3	Cantilever	3	Part Through
4	Cantilever w/ Suspended Span	4*	Combination 1 & 2
5	Arch	5*	Combination 1 & 3
6	Rigid Frame	6*	Combination 2 & 3
7	Movable	7*	Combination 1,2 & 3
8	Suspension or Stayed	9*	Other
9	Other		

Item 37 – Historical Significance: 5

Item 43.1.1 - S = 1

or

Item 43.1.2 – S = 1

$S = 0$

$\therefore Importance\ Index = 0$

Risk Index

<table>
<tr><th colspan="6">Risk Factor</th></tr>
<tr><td>Sub-Factors</td><td>Scour Critical Bridge (Item 113)</td><td colspan="4">STRAHNET Highway Designation</td></tr>
<tr><td rowspan="5">Index Score</td><td rowspan="5">IF Item 113 = 0, 1, 2 or 3 –> Index value =1

Otherwise, Index Value = 0</td><td>Code</td><td colspan="2">Description</td><td>Index Score</td></tr>
<tr><td>0</td><td colspan="2">Not STRAHNET route</td><td>0</td></tr>
<tr><td>1</td><td colspan="2">Interstate STRAHNET route</td><td>1</td></tr>
<tr><td>2</td><td colspan="2">Non-Interstate STRAHNET route</td><td>0.67</td></tr>
<tr><td>3</td><td colspan="2">STRAHNET connector route</td><td>0.33</td></tr>
<tr><td rowspan="3">Risk Score(1) =</td><td colspan="2" rowspan="3">(c)*Scour Critical Index + (d)*STRAHNET Highway Designation Index
Where (c) = 0.5 (suggested weight)
(d) = 0.5 (suggested weight)</td><td>Weight</td><td colspan="2">0-1</td></tr>
<tr><td>(c)</td><td colspan="2">0.5</td></tr>
<tr><td>(d)</td><td colspan="2">0.5</td></tr>
<tr><td>Risk Score (2)* =</td><td colspan="5">STRAHNET Highway Designation Index</td></tr>
</table>

Risk Index = 0.5*Scour Critical + 0.5*STRAHNET Highway Designation

Item 113 (Scour Critical Bridge): 5

Scour Critical Index: 0

STRAHNET Highway Designation: 0

STRAHNET Index: 0

$\therefore$ Risk Index $= 0$

Public Use Index

Public Use Index = 0.5*Traffic + 0.5*Functional Classification

<table>
<tr><th>Traffic</th><th colspan="2">Functional Classification</th></tr>
<tr><td rowspan="5">Traffic Index = 0.5*ADT + 0.5*Detour Length

ADT Index = $0.0231*ADT^{0.3421}$

Detour Length Index = $\frac{Det}{9}$ for Detour Lengths of 0-9.

IF Detour Length > 9, THEN Index Score = 1 (Signifying the maximum detour length considered to be “extreme”)

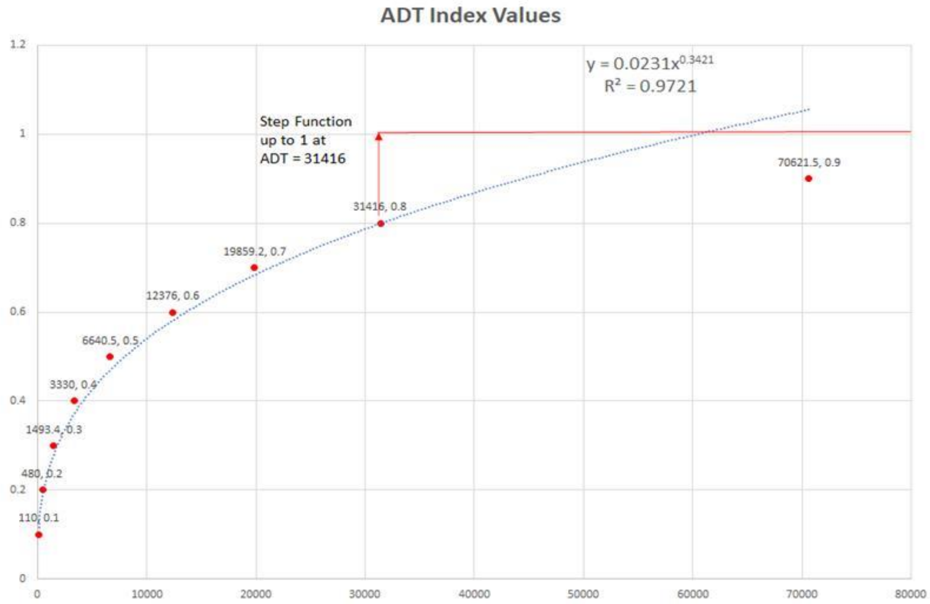
IF Item 5.1 =1
• Bypass Detour Length
• ADT (Index Value = 1 after ADT = 31416) → Refer to Graph 1

IF Item 5.1 = 2
• Intersecting Route ADT (Index Value = 1 after ADT = 23000) → Refer to Graph 2
• Intersecting Route Bypass Detour Length</td><td>Inventory Route Functional Classification</td><td>Index Value</td></tr>
<tr><td>Interstate</td><td>1.000</td></tr>
<tr><td>Other Freeway and Expressway</td><td>0.875</td></tr>
<tr><td>Other Principal Arterial</td><td>0.750</td></tr>
<tr><td>Minor Arterial</td><td>0.625</td></tr>
<tr><td rowspan="4">Insert Opinion for Maximum Detour Length to be attributed to Index Score =1 (extreme detour)

Opinion Detour Length =</td><td>Collector</td><td>0.500</td></tr>
<tr><td>Major</td><td>0.375</td></tr>
<tr><td>Minor</td><td>0.250</td></tr>
<tr><td>Local</td><td>0.125</td></tr>
</table>

Traffic = 0.5*ADT + 0.5*Detour Length

Item 5.1 = 1, ∴ Use ADT Values and Bypass Detour Length Values



ADT Index = $0.0231*ADT^{0.3421} = 0.0231*(7580)^{0.3421} = 0.4907$

Bypass Detour Length = 1

Item 19 - Detour Length Index = $\frac{1}{9}$ = 0.111

Traffic Index = 0.5*0.4907 + 0.5*0.111 = 0.30

Item 26 = Inventory Route Functional Classification = 46 (Local Rd)

Functional Classification Index = 0.125

Public Use Index = 0.5*Traffic + 0.5*Functional Classification = 0.5*0.3 + 0.5*0.125 = 0.2125

Geometry

Geometry Index = 0.45*R + 0.45*W + 0.1*V

R = Rating Reduction = $\frac{A + B + C + D + E + F}{6}$

W = Roadway Width Insufficiency = 0.25*G + 0.75*H for Bridges

V = Vertical Clearance Insufficiency

Rating Reduction					
If Item 58 (DECK_COND_RTNG) is…	**If Item 67 (APPRSL_RTNG_STRUC_EVAL) is…**	**If Item 68 (APPRSL_RTNG_DECK_GMTRY) is…**	**If Item 69 (APPRSL_RTNG_VERT_HRZNTL_UNDR) is…**	**If Item 71 (APPRSL_RTNG_WATRWY) is…**	**If Item 72 (APPRSL_RTNG_APRCH_ALGN) is…**
≤ 3, then $A = 1$	≤ 3, then $B = 1$	≤ 3, then $C = 1$	≤ 3, then $D = 1$	≤ 3, then $E = 1$	≤ 3, then $F = 1$
$= 4$, then $A = 0.6$	$= 4$, then $B = 0.6$	$= 4$, then $C = 0.5$	$= 4$, then $D = 0.5$	$= 4$, then $E = 0.5$	$= 4$, then $F = 0.5$
$= 5$, then $A = 0.2$	$= 5$, then $B = 0.2$	$= 5$, then $C = 0.25$	$= 5$, then $D = 0.25$	$= 5$, then $E = 0.25$	$= 5$, then $F = 0.25$
≥ 6, then $A = 0$	≥ 6, then $B = 0$	≥ 6, then $C = 0$	≥ 6, then $D = 0$	≥ 6, then $E = 0$	≥ 6, then $F = 0$
$=$ N, then $A = 0$	$=$ N, then $B = 0$	$=$ N, then $C = 0$	$=$ N, then $D = 0$	$=$ N, then $E = 0$	$=$ N, then $F = 0$

Item 58 = 8 $\therefore A = 0$

Item 67 = 4 $\therefore B = 0.6$

Item 68 = 2 $\therefore C = 1$

Item 69 = N $\therefore D = 0$

Item 71 = 7 $\therefore E = 0$

Item 72 = 8 $\therefore F = 0$

$$R = \frac{0+0.6+1+0+0+0}{6} = 0.267$$

(1) For all bridges except culverts	(2) For one-lane bridges including one-lane culverts	(3) For bridges with two or more lanes (including culverts)
• If Item 43.4 (CULV_MEMB_TYPE) is blank or 0 and; • If Item 51 (BRDG_RDWAY_WIDTH_CURB_CURB) + 2 ft < Item 32 (APRCH_RDWAY_WIDTH), then G = 1 • If Item 51 (BRDG_RDWAY_WIDTH_CURB_CURB) + 2 ft • Item 32 (APRCH_RDWAY_WIDTH), then G = 0.	• If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 01 and; • If Y < 14, then H = 1 • If 14 ≤ Y but < 18, then H = 0.25 [(18 – Y)/4]. • If Y ≥ 18, then H = 0.	• If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 02 and Y ≥ 16, then H = 0. • If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 03 and Y ≥ 15, then H = 0. • If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 04 and Y ≥ 14, then H = 0. • If the first two digits of Item 28 ($LANES\_ON\_STRUC$) = 05 and Y ≥ 12, then H = 0. If any one of the preceding conditions is met, do not continue trying to determine H because no lane width reductions are necessary. Otherwise, determine H based on the following: values for X and Y: • If X≤ 50 and Y < 9, then H = 0.5 • If X≤ 50 and Y≥ 9, then H = 0. • If 50 < X ≤125 and Y < 10, then H = 1. • If 50 < X ≤125 and 10 ≤Y < 13, then H = 0.33 [(13 - Y)/3] • If 50 < X ≤125 and Y ≥13, then H = 0 • If 125 < X ≤375 and Y < 11, then H = 1 • If 125 < X ≤375 and 11≤ Y < 14, then H = 0.33 [(14 - Y)/3] • If 125 < X ≤375 and Y ≥14, then H = 0 • If 375 < X≤ 1350 and Y < 12, then H = 1 • If 375 < X≤ 1350 and 12 ≤ Y < 16, then H = 0.25 [(16 - Y)/4] • If 375 < X ≤1350 and Y ≥16, then H = 0 • If X > 1350 and Y < 15, then H =1 • If X > 1350 and 15≤ Y < 16, then H = 1 (16 - Y) • If X > 1350 and Y ≥16, then H = 0

Item 51 = 36.5 ft + 2 ft = 38.5 ft

Item 32 = 37

Item 51 > Item 32, **G = 0**

Item 28 = 03

Criteria for W, Roadway Width Insufficiency (G+H):

Find X and Y:

$$Y = \frac{BRDG\_RDWAY\_WIDTH\_CURB\_CURB\ (Item\ 51)}{LANES\_ON\_STRUC\ (Item\ 28)}$$

$$X = \frac{ADT\ (Item\ 29)}{LANES\_ON\_STRUC\ (Item\ 28)}$$

$$Y = \frac{36.5}{3} = 12.1667 < 15$$

X = $\frac{7580}{03} = 2526.7$ > 1350

$\therefore H = 1$

∴ W = Roadway Width Insufficiency = 0.25*G + 0.75*H for Bridges

$\therefore\ W = 0.25 * 0 + 0.75 * 1 = 0.75$

Vertical Clearance

V is a Vertical Clearance Insufficiency set by the following:

If Item 100 (STRAHNET) > 0 and;

Item 53 (Min Vert Clearance Over Bridge Deck) > 1600 then V = 0

Item 53 (Min Vert Clearance Over Bridge Deck) < 1600 then V = 1

If Item 100 (STRAHNET) = 0 and;

Item 53 (Min Vert Clearance Over Bridge Deck) > 1400 then V = 0

Item 53 (Min Vert Clearance Over Bridge Deck) < 1400 then V = 1

Item 100 = 0

Item 53 = 99.99 ft

V = 1

$\therefore Geometry =$ 0.45*R + 0.45*W + 0.1*V

$\therefore Geometry =$ 0.45*0.267 + 0.45*0.75 + 0.1*1 = 0.558

Off-System PR

Off-System Weights	
Factor	**Weights**
Condition	3.9
Geometry	1.8
Public Use	1.5
Risk	1.6
Age	0.8
Importance	0.4
Sum	**10.00**

Off-System PR = 3.9*0.167 + 1.8*0.558 +1.5*0.2125 + 1.6*0.267 + 0.8*0.39 + 0.4*0 = 2.7136 ≈ 3

APPENDIX F

BridgeRep EXCEL VBA Code

EXCEL VBA Code

3.1.1 Condition Factor (On-System) Code	Comments
Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("TxDOT Open Data Portal Data") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Condition Factor (On-System)") '1. Find last used row in the copy range based on data in column A lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "D").End(xlUp).Row '2. Copy & Paste Data wsCopy.Range("D2:D" & lCopyLastRow).Copy wsDest.Range("A3").PasteSpecial xlPasteValues wsCopy.Range("DE2:DE" & lCopyLastRow).Copy wsDest.Range("B3") wsCopy.Range("DB2:DB" & lCopyLastRow).Copy wsDest.Range("C3").PasteSpecial xlPasteValues	

```
  wsCopy.Range("CV2:CV" & lCopyLastRow).Copy
 wsDest.Range("G3").PasteSpecial xlPasteValues
  wsCopy.Range("CW2:CW" & lCopyLastRow).Copy
 wsDest.Range("H3").PasteSpecial xlPasteValues
  wsCopy.Range("CX2:CX" & lCopyLastRow).Copy
 wsDest.Range("I3").PasteSpecial xlPasteValues
 wsCopy.Range("CZ2:CZ" & lCopyLastRow).Copy
 wsDest.Range("J3").PasteSpecial xlPasteValues
wsCopy.Range("EP2:EP" & lCopyLastRow).Copy
 wsDest.Range("O3").PasteSpecial xlPasteValues

 Application.DisplayAlerts = True

End Sub
Sub normalizeBridgeID()
  With Sheets("Condition Factor (On-System)")
 finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
   For Each cell In Worksheets("Condition Factor (On-System)").Range("A3:A" & finalRow).Cells
       cell.Value = cell.Value
   Next
   Range("A3").Select
   Range(Selection, Selection.End(xlDown)).Select
   Selection.NumberFormat = "0.00"
   Selection.NumberFormat = "0.0"
   Selection.NumberFormat = "0"
End Sub

Sub copyFinalSIValues()
Application.ScreenUpdating = False
```

```
Application.DisplayAlerts = False

Dim wsCopy As Worksheet
Dim wsDest As Worksheet
Dim lCopyLastRow As Long
Dim lDestLastRow As Long

  'Set variables for copy and destination sheets
  Set wsCopy = Workbooks("BridgeRep
1.0.xlsm").Worksheets("Severity Index")
  Set wsDest = Workbooks("BridgeRep
1.0.xlsm").Worksheets("Condition Factor (On-System)")

  '1. Find last used row in the copy range based on data in
column A
  lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count,
"I").End(xlUp).Row

  '2. Copy & Paste Data
  wsCopy.Range("K2:K" & lCopyLastRow).Copy
  wsDest.Range("M3").PasteSpecial xlPasteValues
  wsCopy.Range("P2:P" & lCopyLastRow).Copy
  wsDest.Range("N3").PasteSpecial xlPasteValues

 Application.DisplayAlerts = True

End Sub

Sub calculateDSS()
Worksheets("Condition Factor (On-System)").Activate
   With Sheets("Condition Factor (On-System)")
```

lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("L3").Formula = "=IFERROR(0.5*K3+0.5*Q3,"""")" Range("L3").AutoFill Range("L3:L" & lastRow) End Sub Sub indexValue() Worksheets("Condition Factor (On-System)").Activate With Sheets("Condition Factor (On-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("D3").Formula = "=B3/36" Range("D3").AutoFill Range("D3:D" & finalRow) Range("E3").Formula = "=C3/36" Range("E3").AutoFill Range("E3:E" & finalRow) Range("F3").Formula = "=IF(OR(C3<3,E3<1),1,IF(AND(B3>=3,B3<=36),- (1/33)*B3+(12/11),0))" Range("F3").AutoFill Range("F3:F" & finalRow) End Sub Sub NBI() With Sheets("Condition Factor (On-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With	 Column K refers to NBI Column Q refers to Bridge SI (On-System)

Range("K3").Formula = "=IF(OR(G3 = ""N"",H3 = ""N"", I3 = ""N""), 1-J3/9, 1-(G3+H3+I3)/27)" Range("K3").AutoFill Range("K3:K" & finalRow) End Sub Sub conditionIndex() With Sheets("Condition Factor (On-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("P3").Formula = "=IFERROR(0.5*L3+0.5*F3,"""")" Range("P3").AutoFill Range("P3:P" & finalRow) End Sub Sub convertToDecimals() With Sheets("Condition Factor (On-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Dim rng As Range Set rng = Range("D3:D" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("E3:E" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("K3:K" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("F3:F" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("L3:L" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("Q3:Q" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("N3:N" & finalRow) rng.NumberFormat = "0.00"	Column G refers to DECK_COND_RTNG Column H refers to SUPERSTRUC_COND_RTNG Column I refers to SUBSTRUC_COND_RTNG Column L refers to INV_RTE_HWY_SYS Column F refers to LRF Index

```
  Set rng = Range("P3:P" & finalRow)
  rng.NumberFormat = "0.00"
End Sub
Sub BridgeSIForOnSystem()
 With Sheets("Condition Factor (On-System)")
  finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
finalRowUnique =
Range("M3").SpecialCells(xlCellTypeLastCell).Row
Range("Q3").Formula =
"=IFERROR(INDEX($N$3:$N$" & finalRowUnique &
", MATCH(A3,$M$3:$M$" & finalRowUnique &
")),"""")"
Range("Q3").AutoFill Range("Q3:Q" & finalRow)
End Sub

Sub DropDown()
If Sheet1.Shapes("DropDownButton").Visible Then
Sheet1.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet1.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub
Sub hideAndShowConditionFactorFormula()
If Sheet1.Shapes("ConditionFactorFormula").Visible
Then
Sheet1.Shapes("ConditionFactorFormula").Visible =
msoFalse
Else
Sheet1.Shapes("ConditionFactorFormula").Visible =
msoTrue
```

End If End Sub Sub allInOneConditionFactorOn() With Sheets("Condition Factor (On-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Load LoadingScreen LoadingScreen.Show vbModeless DoEvents Range("A3:Q" & finalRow & "").Clear copyFromMainFile 'normalizeBridgeID copyFinalSIValues indexValue NBI BridgeSIForOnSystem calculateDSS conditionIndex convertToDecimals Unload LoadingScreen End Sub	
3.1.2 Condition Factor (Off System) Code	Comments
Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet	

```
Dim lCopyLastRow As Long
Dim lDestLastRow As Long

  'Set variables for copy and destination sheets
  Set wsCopy = Workbooks("BridgeRep
1.0.xlsm").Worksheets("TxDOT Open Data Portal
Data")
  Set wsDest = Workbooks("BridgeRep
1.0.xlsm").Worksheets("Condition Factor (Off-System)")

  '1. Find last used row in the copy range based on data in
column A
  lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count,
"D").End(xlUp).Row

  '2. Copy & Paste Data
  wsCopy.Range("D2:D" & lCopyLastRow).Copy
  wsDest.Range("A3").PasteSpecial xlPasteValues
  wsCopy.Range("DE2:DE" & lCopyLastRow).Copy
wsDest.Range("B3")
  wsCopy.Range("DB2:DB" & lCopyLastRow).Copy
  wsDest.Range("C3").PasteSpecial xlPasteValues
   wsCopy.Range("CV2:CV" & lCopyLastRow).Copy
  wsDest.Range("G3").PasteSpecial xlPasteValues
   wsCopy.Range("CW2:CW" & lCopyLastRow).Copy
  wsDest.Range("H3").PasteSpecial xlPasteValues
   wsCopy.Range("CX2:CX" & lCopyLastRow).Copy
  wsDest.Range("I3").PasteSpecial xlPasteValues
 wsCopy.Range("CZ2:CZ" & lCopyLastRow).Copy
  wsDest.Range("J3").PasteSpecial xlPasteValues
  wsCopy.Range("EP2:EP" & lCopyLastRow).Copy
```

`wsDest.Range("L3").PasteSpecial xlPasteValues`
 	
`Application.DisplayAlerts = True`
 	
`End Sub`
`Sub normalizeBridgeID()`
`With Sheets("Condition Factor (Off-System)")`
`finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row`
`End With`
`For Each cell In Worksheets("Condition Factor (Off-System)").Range("A3:A" & finalRow).Cells`
 	
`cell.Value = cell.Value`
 	
`Next`
`Range("A3").Select`
`Range(Selection, Selection.End(xlDown)).Select`
`Selection.NumberFormat = "0.00"`
`Selection.NumberFormat = "0.0"`
`Selection.NumberFormat = "0"`
`End Sub`
`Sub indexValue()`
`Worksheets("Condition Factor (Off-System)").Activate`
`With Sheets("Condition Factor (Off-System)")`
`finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row`
`End With`
`Range("D3").Formula = "=B3/36"`
`Range("D3").AutoFill Range("D3:D" & finalRow)`
	
	Column B refers to INV_RTNG_GROSS_LDNG_TONS

`Range("E3").Formula = "=C3/36"`	Column C refers to OPRTG_RTNG_GROSS_LDNG_TONS

Range("E3").AutoFill Range("E3:E" & finalRow)	
Range("F3").Formula = "=IF(OR(C3<3,E3<1),1,IF(AND(B3>=3,B3<=36),-(1/33)*B3+(12/11),0))"	Column C refers to OPRTG_RTNG_GROSS_LDNG_TONS Column E refers to Rating Factor (OPRTG)
Range("F3").AutoFill Range("F3:F" & finalRow)	Column B refers to INV_RTNG_GROSS_LDNG_TONS
End Sub Sub NBI() With Sheets("Condition Factor (Off-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With	
Range("K3").Formula = "=IF(OR(G3 = ""N"",H3 = ""N"", I3 = ""N""), 1-J3/9, 1-(G3+H3+I3)/27)" Range("K3").AutoFill Range("K3:K" & finalRow) End Sub Sub conditionIndex()	Column G DECK_COND_RTNG Column H refers to SUPERSTRUC_COND_RTNG Column I refers to SUBSTRUC_COND_RTNG Column J refers to CULV_COND_RTNG
With Sheets("Condition Factor (Off-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With	
Range("M3").Formula = "=0.5*K3+0.5*F3" Range("M3").AutoFill Range("M3:M" & finalRow)	Column K refers to NBI Column F refers to LRF Index
End Sub Sub convertToDecimals() With Sheets("Condition Factor (Off-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Dim rng As Range Set rng = Range("D3:D" & finalRow) rng.NumberFormat = "0.00"	

```
  Set rng = Range("E3:E" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("F3:F" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("K3:K" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("L3:L" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("M3:M" & finalRow)
  rng.NumberFormat = "0.00"
End Sub

Sub DropDown()
If Sheet27.Shapes("DropDownButton").Visible Then
Sheet27.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet27.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub
Sub hideAndShowConditionFactorFormula()
If Sheet27.Shapes("ConditionFactorFormula").Visible
Then
Sheet27.Shapes("ConditionFactorFormula").Visible =
msoFalse
Else
Sheet27.Shapes("ConditionFactorFormula").Visible =
msoTrue
End If
End Sub
```

Sub allInOneConditionFactorOff() With Sheets("Condition Factor (Off-System)") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Load LoadingScreen LoadingScreen.Show vbModeless DoEvents Range("A3:I" & finalRow & "").Clear copyFromMainFile 'normalizeBridgeID NBI indexValue conditionIndex convertToDecimals Unload LoadingScreen End Sub	
3.1.3 Importance Factor Code	Comments
Sub calculateHistoricalImpFactor() Worksheets("Importance").Activate lastRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row Range("C3").Formula = "=IF(B3=1, 1, IF(B3= 2, 0.75, IF(B3=3, 0.5, IF(B3= 4, 0.25, IF(B3= 5, 0, NA)))))" Range("C3").AutoFill Range("C3:C" & lastRow) End Sub Sub calculateSpecialBridges()	Column B refers to HIST_SIG

Worksheets("Importance").Activate lastRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row Range("E3").Formula = "=IF(F3 = 2, 1, IF(F3 = 3, 1, IF(F3 = 4, 1, IF(F3 = 5, 1,IF(F3 = 6, 1,IF(F3 = 7, 1,IF(D3 = 8, 1,IF(D3 = 7, 1,0))))))))" Range("E3").AutoFill Range("E3:E" & lastRow) End Sub Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("TxDOT Open Data Portal Data") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Importance") '1. Find last used row in the copy range based on data in column A lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "D").End(xlUp).Row	Column F refers RDWAY_TYPE Column D refers SPAN_TYPE

<pre> '2. Copy & Paste Data
  wsCopy.Range("D2:D" & lCopyLastRow).Copy
wsDest.Range("A3")
  wsCopy.Range("BA2:BA" & lCopyLastRow).Copy
  wsDest.Range("B3").PasteSpecial xlPasteValues
  wsCopy.Range("BJ2:BJ" & lCopyLastRow).Copy
  wsDest.Range("D3").PasteSpecial xlPasteValues
  wsCopy.Range("BK2:BK" & lCopyLastRow).Copy
  wsDest.Range("F3").PasteSpecial xlPasteValues
 	
 Application.DisplayAlerts = True
 	
End Sub
Sub normalizeBridgeID()
Worksheets("Importance").Activate
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
    For Each cell In
Worksheets("Importance").Range("A3:A" &
finalRow).Cells
 	
        cell.Value = cell.Value
 	
    Next
    Range("A3").Select
    Range(Selection, Selection.End(xlDown)).Select
    Selection.NumberFormat = "0.00"
    Selection.NumberFormat = "0.0"
    Selection.NumberFormat = "0"</pre>	

End Sub Sub calculateIndexScores() Worksheets("Importance").Activate lastRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row Range("G3").Formula = "=IF(AND(C3>0,E3 = 0),C3, IF(AND(C3>0,E3 = 1),1,IF(AND(C3 = 0,E3 = 1),1, 0)))" Range("G3").AutoFill Range("G3:G" & lastRow) End Sub Sub AllInOneHistoricalImportance() finalRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row Load LoadingScreen LoadingScreen.Show vbModeless DoEvents Range("A3:G" & finalRow & "").Clear copyFromMainFile 'normalizeBridgeID calculateHistoricalImpFactor calculateSpecialBridges calculateIndexScores convertToDecimals Unload LoadingScreen End Sub Sub timeFrame(pauseTime As Double) Start = Timer Do DoEvents Loop Until (Timer - Start) >= pauseTime End Sub	Column C refers to Historical Importance Index Column E refers Special Bridge Index

Sub DropDown()
If Sheet3.Shapes("DropDownButton").Visible Then
Sheet3.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet3.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub
 	
Sub HideandShowReferenceValues()
If Sheet3.Shapes("ReferenceValues").Visible Then
Sheet3.Shapes("ReferenceValues").Visible = msoFalse
Else
Sheet3.Shapes("ReferenceValues").Visible = msoTrue
End If
End Sub
Sub convertToDecimals()
With Sheets("Age Factor")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Dim rng As Range
Set rng = Range("C3:C" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("G3:G" & finalRow)
rng.NumberFormat = "0.00"
 	
End Sub	

3.1.4 Age Factor Code	Comments
Sub calculateAgeFactor()	

Worksheets("Age Factor").Activate lastRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row Range("C3").Formula = "=YEAR(TODAY())-B3" Range("C3").AutoFill Range("C3:C" & lastRow) Range("D3").Formula = "=IF(C3>75, 1, IF(C3>= 51, 0.63, IF(C3>=26, 0.39, 0)))" Range("D3").AutoFill Range("D3:D" & lastRow) End Sub Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("TxDOT Open Data Portal Data") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Age Factor")	Column B refers YR_BLT Column C refers to Age

'1. Find last used row in the copy range based on data in column A lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "D").End(xlUp).Row '2. Copy & Paste Data wsCopy.Range("D2:D" & lCopyLastRow).Copy wsDest.Range("A3") wsCopy.Range("AM2:AM" & lCopyLastRow).Copy wsDest.Range("B3").PasteSpecial xlPasteValues Application.DisplayAlerts = True End Sub Sub normalizeBridgeID() finalRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row For Each cell In Worksheets("Age Factor").Range("A3:A" & finalRow).Cells cell.Value = cell.Value Next Range("A3").Select Range(Selection, Selection.End(xlDown)).Select Selection.NumberFormat = "0.00" Selection.NumberFormat = "0.0" Selection.NumberFormat = "0" End Sub Sub AllInOneAgeFactor()	

```
lastRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
Load LoadingScreen
LoadingScreen.Show vbModeless
DoEvents
Range("A3:D" & lastRow & "").Clear
copyFromMainFile
'normalizeBridgeID
calculateAgeFactor
convertToDecimals
Unload LoadingScreen
End Sub

Sub SlidingPanel()
If Range("A:b").EntireColumn.Hidden = False Then
   ActiveSheet.Shapes.Range(Array("arrow")).Select
   Selection.ShapeRange.IncrementRotation 180
   Range("A:b").EntireColumn.Hidden = True
   Range("a1").Select
Else
   ActiveSheet.Shapes.Range(Array("arrow")).Select
   Selection.ShapeRange.IncrementRotation -180
   Range("A:b").EntireColumn.Hidden = False
   Range("a1").Select
End If
End Sub
Sub timeFrame(pauseTime As Double)
Start = Timer
Do
DoEvents
Loop Until (Timer - Start) >= pauseTime
```

End Sub
 	
Sub DropDown()
If Sheet2.Shapes("DropDownButton").Visible Then
Sheet2.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet2.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub
 	
Sub HideandShowGraph()
If Sheet2.Shapes("AgeGraph").Visible Then
Sheet2.Shapes("AgeGraph").Visible = msoFalse
Else
Sheet2.Shapes("AgeGraph").Visible = msoTrue
End If
End Sub
Sub HideandShowIndexValues()
If Sheet2.Shapes("IndexScores").Visible Then
Sheet2.Shapes("IndexScores").Visible = msoFalse
Else
Sheet2.Shapes("IndexScores").Visible = msoTrue
End If
End Sub
Sub convertToDecimals()
With Sheets("Age Factor")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Dim rng As Range
Set rng = Range("D3:D" & finalRow)
rng.NumberFormat = "0.00"	

End Sub	
3.1.4 Risk Factor Code	Comments
Sub calculateRiskFactor() Worksheets("Risk Factor").Activate lastRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row Range("E3").Formula = "=IF(C3=0, 0, IF(C3= 1, 1, IF(C3=2, 0.67, IF(C3= 3, 0.33, NA))))" Range("E3").AutoFill Range("E3:E" & lastRow) Range("F3").Formula = "=IF(B3=""N"",0,IF(B3=0,1,IF(B3=1,1,IF(B3=2,1,IF(B3=3,-0.1667*B3+1.5,IF(B3=4,-0.1667*B3+1.5,IF(B3=5,-0.1667*B3+1.5,IF(B3=6,-0.1667*B3+1.5,IF(B3=7,-0.1667*B3+1.5,IF(B3=8,-0.1667*B3+1.5,IF(B3=9,-0.1667*B3+1.5,0)))))))))))" Range("F3").AutoFill Range("F3:F" & lastRow) Range("D3").Formula = "=0.5*F3+0.5*E3" Range("D3").AutoFill Range("D3:D" & lastRow) End Sub	Column C refers to STRAHNET_HWY_DSGNAT Column B refers SCOUR_CRIT Column F refers to Scour Critical Index Column E refers to STRAHNET Highway Designation Index Score

Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("TxDOT Open Data Portal Data") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Risk Factor") '1. Find last used row in the copy range based on data in column A lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "D").End(xlUp).Row '2. Copy & Paste Data wsCopy.Range("D2:D" & lCopyLastRow).Copy wsDest.Range("A3").PasteSpecial xlPasteValues wsCopy.Range("FJ2:FJ" & lCopyLastRow).Copy wsDest.Range("B3").PasteSpecial xlPasteValues wsCopy.Range("EL2:EL" & lCopyLastRow).Copy wsDest.Range("C3").PasteSpecial xlPasteValues	

Application.DisplayAlerts = True
 	
End Sub
Sub normalizeBridgeID()
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
    For Each cell In Worksheets("Risk
Factor").Range("A3:A" & finalRow).Cells
 	
        cell.Value = cell.Value
 	
    Next
    Range("A3").Select
    Range(Selection, Selection.End(xlDown)).Select
    Selection.NumberFormat = "0.00"
    Selection.NumberFormat = "0.0"
    Selection.NumberFormat = "0"
End Sub
Sub convertToDecimals()
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
Dim rng As Range
  Set rng = Range("D3:D" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("F3:F" & finalRow)
  rng.NumberFormat = "0.00"
End Sub
 	
Sub AllInOneRiskFactor()
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row	

Load LoadingScreen
LoadingScreen.Show vbModeless
DoEvents
Range("A3:F" & finalRow & "").Clear
copyFromMainFile
'normalizeBridgeID
calculateRiskFactor
convertToDecimals
Unload LoadingScreen
End Sub
 	
Sub timeFrame(pauseTime As Double)
Start = Timer
Do
DoEvents
Loop Until (Timer - Start) >= pauseTime
End Sub
 	
Sub DropDown()
If Sheet4.Shapes("DropDownButton").Visible Then
Sheet4.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet4.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub
 	
Sub HideandShowReferenceValues()
If Sheet4.Shapes("ReferenceValues").Visible Then
Sheet4.Shapes("ReferenceValues").Visible = msoFalse
Else	

Sheet4.Shapes("ReferenceValues").Visible = msoTrue
End If
End Sub
Sub
HideandShowSTRAHNETHighwayDesignationValues()
If
Sheet4.Shapes("STRAHNETHighwayDesignation").Visible Then
Sheet4.Shapes("STRAHNETHighwayDesignation").Visible = msoFalse
Else
Sheet4.Shapes("STRAHNETHighwayDesignation").Visible = msoTrue
End If
End Sub	

3.1.5 Public Use Factor Code	Comments

Sub calculatePublicFactorIndexValue()
 	
Worksheets("Public Use Factor").Activate
'Inventory Route Functional Classification Index Value
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
 	
For i = finalRow To 3 Step -1
    If Range("B" & i).Value = 11 Or Range("B" & i).Value = 21 Or Range("B" & i).Value = 41 Or Range("B" & i).Value = 1 Then
    Range("F" & i) = "1.000"	

ElseIf Range("B" & i).Value = 12 Or Range("B" & i).Value = 22 Or Range("B" & i).Value = 42 Then Range("F" & i) = "0.875" ElseIf Range("B" & i).Value = 13 Or Range("B" & i).Value = 23 Or Range("B" & i).Value = 43 Or Range("B" & i).Value = 2 Then Range("F" & i) = "0.750" ElseIf Range("B" & i).Value = 14 Or Range("B" & i).Value = 24 Or Range("B" & i).Value = 44 Or Range("B" & i).Value = 3 Then Range("F" & i) = "0.625" ElseIf Range("B" & i).Value = 15 Or Range("B" & i).Value = 25 Or Range("B" & i).Value = 45 Then Range("F" & i) = "0.500" ElseIf Range("B" & i).Value = 4 Then Range("F" & i) = "0.375" ElseIf Range("B" & i).Value = 5 Then Range("F" & i) = "0.250" ElseIf Range("B" & i).Value = 16 Or Range("B" & i).Value = 26 Or Range("B" & i).Value = 46 Or Range("B" & i).Value = 6 Then Range("F" & i) = "0.125" End If Next i	

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'ADT Index Value
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row

For i = finalRow To 3 Step -1
    If Range("C" & i).Value < 31416 Then
    Range("H" & i).Formula = "=0.0231*POWER(C" & i & ",0.3421)"
    Else
    Range("H" & i) = 1
    End If
  Next i

'Detour Index Value
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row

For i = finalRow To 3 Step -1
    If Range("D" & i).Value < 9 Then
    Range("I" & i).Formula = "=D" & i & "/9"
    Else
    Range("I" & i) = 1
    End If
  Next i

'Traffic
lastRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
Range("E3").Formula = "=0.5*H3+0.5*I3"
Range("E3").AutoFill Range("E3:E" & lastRow)

</td>
<td>

Column C refers to ADT
Column I refers to Detour Length Index

Column D refers to DETOUR_LNGTH
Column I refers to Detour Length Index

Column H refers to ADT Index Value
Column I refers to Detour Length Index

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</tr>
</table>

'Public Use Index lastRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row Range("G3").Formula = "=0.5*F3+0.5*E3" Range("G3").AutoFill Range("G3:G" & lastRow) End Sub Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("TxDOT Open Data Portal Data") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Public Use Factor") '1. Find last used row in the copy range based on data in column A	Column F refers to Inventory Route Functional Classification Index Value Column E refers to Traffic

lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "D").End(xlUp).Row '2. Copy & Paste Data wsCopy.Range("D2:D" & lCopyLastRow).Copy wsDest.Range("A3").PasteSpecial xlPasteValues wsCopy.Range("AL2:AL" & lCopyLastRow).Copy wsDest.Range("B3").PasteSpecial xlPasteValues wsCopy.Range("AP2:AP" & lCopyLastRow).Copy wsDest.Range("C3").PasteSpecial xlPasteValues wsCopy.Range("AE2:AE" & lCopyLastRow).Copy wsDest.Range("D3").PasteSpecial xlPasteValues Application.DisplayAlerts = True End Sub Sub normalizeBridgeID() finalRow = Range("A3").SpecialCells(xlCellTypeLastCell).Row For Each cell In Worksheets("Public Use Factor").Range("A3:A" & finalRow).Cells cell.Value = cell.Value Next Range("A3").Select Range(Selection, Selection.End(xlDown)).Select Selection.NumberFormat = "0.00" Selection.NumberFormat = "0.0" Selection.NumberFormat = "0" End Sub	

```
Sub AllInOnePublicUseFactor()
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
Load LoadingScreen
LoadingScreen.Show vbModeless
DoEvents
Range("A3:I" & finalRow & "").Clear
copyFromMainFile
'normalizeBridgeID
calculatePublicFactorIndexValue
convertToDecimals
Unload LoadingScreen
End Sub
Sub timeFrame(pauseTime As Double)
Start = Timer
Do
DoEvents
Loop Until (Timer - Start) >= pauseTime
End Sub

Sub convertToDecimals()
finalRow =
Range("A3").SpecialCells(xlCellTypeLastCell).Row
Dim rng As Range
  Set rng = Range("E3:E" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("F3:F" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("G3:G" & finalRow)
  rng.NumberFormat = "0.00"
```

```
  Set rng = Range("H3:H" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("I3:I" & finalRow)
  rng.NumberFormat = "0.00"
End Sub
Sub DropDown()
If Sheet6.Shapes("DropDownButton").Visible Then
Sheet6.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet6.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub

Sub HideandShowADTReferenceValues()
If Sheet6.Shapes("IntersectingRouteADT").Visible Then
Sheet6.Shapes("IntersectingRouteADT").Visible =
msoFalse
Sheet6.Shapes("ADTIndexValues").Visible = msoFalse
Else
Sheet6.Shapes("IntersectingRouteADT").Visible =
msoTrue
Sheet6.Shapes("ADTIndexValues").Visible = msoTrue
End If
End Sub
Sub HideandShowPublicUseFormula()
If Sheet6.Shapes("PublicUseFormula").Visible Then
Sheet6.Shapes("PublicUseFormula").Visible = msoFalse
Else
Sheet6.Shapes("PublicUseFormula").Visible = msoTrue
End If
End Sub
```

3.1.6 EROR Code	Comments
Sub AllInOneFileEROR() Worksheets("EROR").Activate With Sheets("EROR") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Load LoadingScreen LoadingScreen.Show vbModeless DoEvents Range("C3:G" & lastRow & "").Clear Range("J3:V" & lastRow & "").Clear copyFromMainFile CopyLocalSIandAssetCode normalizeOnSystemAssetCodes 'normalizeBridgeID featureCrossed featureIndex elementsCrossed RelativeElementWeight localSIAndRelativeWeights sumOfRelativeWeights summationOfLocalSIandRelativeWeights componentDamaged finalFeatureCrossed ERORIndex convertToDecimals	

Unload LoadingScreen End Sub Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("TxDOT Open Data Portal Data") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("EROR") '1. Find last used row in the copy range based on data in column A lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "D").End(xlUp).Row '2. Copy & Paste Data wsCopy.Range("D2:D" & lCopyLastRow).Copy wsDest.Range("G3").PasteSpecial xlPasteValues wsCopy.Range("CZ2:CZ" & lCopyLastRow).Copy wsDest.Range("F3").PasteSpecial xlPasteValues wsCopy.Range("W2:W" & lCopyLastRow).Copy wsDest.Range("C3").PasteSpecial xlPasteValues wsCopy.Range("L2:L" & lCopyLastRow).Copy	

wsDest.Range("J3").PasteSpecial xlPasteValues Application.DisplayAlerts = True End Sub Sub normalizeBridgeID() finalRow = Range("G3").SpecialCells(xlCellTypeLastCell).Row 'For Each cell In Worksheets("EROR").Range("G3:G" & finalRow).Cells 'cell.Value = cell.Value ' Next Range("G3").Select Range(Selection, Selection.End(xlDown)).Select Selection.NumberFormat = "0.00" Selection.NumberFormat = "0.0" Selection.NumberFormat = "0" End Sub Sub featureCrossed() 'Feature Crossed	
finalRow = Range("C3").SpecialCells(xlCellTypeLastCell).Row Range("D3").Formula = "=IF(F3=""N"",IF(OR(COUNTIF(C3,""*CREEK*""),COUNTIF(C3,""*TRIB*""),COUNTIF(C3,""*BR*""),COUNTIF(C3,""*BRANCH*""),COUNTIF(C3,""*DRAW*""),COUNTIF(C3,""*TYLR*""),COUNTIF(C3,""*CK*""),COUNTIF(C3,""*RI*""),COUNTIF(C3,""*CRK*""), COUNTIF(C3,""*RIVER*""),COUNTIF(C3,""*LAKE*	Column C refers to FEAT_INTSECT Column F refers to CULV_COND_RTNG

""),COUNTIF(C3,""*TAYLOR*""),COUNTIF(C3,""*F K TR*""),COUNTIF(C3,""*QUILL*""),COUNTIF(C3,""* DITCH*""),COUNTIF(C3,""*WILLOW BEND*""),COUNTIF(C3,""*TAYLR*"")),$H$3,IF(OR(COUNTIF(C3,""*RAILROAD*""),COUNTIF(C3,""*SP 580*""),COUNTIF(C3,""*HIGHWAY*""),COUNTIF(C 3,""*TRANSIT*""),COUNTIF(C3,""*RR*""),COUNTI F(C3,""*R/R*""),COUNTIF(C3,""*DART*""),COUNTI F(C3,""*RAILTRAN*""),COUNTIF(C3,""*TEXRAIL* ""),COUNTIF(C3,""*FWWR*"")),$H$5,IF(OR(COUNT IF(C3,""*US*""),COUNTIF(C3,""*RAMP*""),COUNTI F(C3,""*BNSF*""),COUNTIF(C3,""*SH*""),COUNTIF (C3,""*FM*""),COUNTIF(C3,""*IH*"")," & _ "COUNTIF(C3,""*820 GP & 35 ML*""),COUNTIF(C3,""*CONN SE SB I35W EXIT*""),COUNTIF(C3,""*30 EB CD 360 FR Six Fl*""),COUNTIF(C3,""*30 CD Lamar Johnson Ck*""),COUNTIF(C3,""*SPUR 341*""),COUNTIF(C3,""*CONNECTION A B E H*""),COUNTIF(C3,""*I 30*"")," & _ "COUNTIF(C3,""*INTERNATIONAL PKWY*""),COUNTIF(C3,""*CR*""),COUNTIF(C3,""* RD*""),COUNTIF(C3,""*SPUR*""),COUNTIF(C3,""*I NTL SB S SVC W ACC*""),COUNTIF(C3,""*AVE*""),COUNTIF(C3,""* ST*""),COUNTIF(C3,""*ROAD*""),COUNTIF(C3,""* STREET*""),COUNTIF(C3,""*TRAIL*""),COUNTIF(C3,""*DON LEE*""),COUNTIF(C3,""*NATURAL GROUND*""),COUNTIF(C3,""*BLVD*""),COUNTIF(C3,""*NB*""),COUNTIF(C3,""*LANE*""),COUNTIF(	

C3,""*ROW*""),COUNTIF(C3,""*SB*""),COUNTIF(C 3,""*DRIVE*"")*COUNTIF(C3,""*DR*""),COUNTIF(C3,""*RM*""),COUNTIF(C3,""*BU*""),COUNTIF(C3, ""*PARKWAY*""),COUNTIF(C3,""*PKWY*""),COU NTIF(C3,""*TCC BUILDING*""),COUNTIF(C3,""*LN*""),COUNTIF(C 3,""*WB*""),COUNTIF(C3,""*LAND*""),COUNTIF(C 3,""*PARKING LOT*""),COUNTIF(C3,""*LOOP*""),COUNTIF(C3,"" *CONNECTION*""),COUNTIF(C3,""*OVERPASS*"") ,COUNTIF(C3,""*OPEN AREA*""),COUNTIF(C3,""*DR*""),COUNTIF(C3,""* ACCESS*"")),$H$4,""""))),""Waterway"")" Range("D3").AutoFill Range("D3:D" & finalRow) End Sub Sub featureIndex() 'Feature Index finalRow = Range("D3").SpecialCells(xlCellTypeLastCell).Row Range("E3").Formula = "=IF(D3=""WATERWAY"",$I$3,IF(D3=""ROADWAY "",$I$4,IF(D3=""RAILROAD"",$I$5,"""")))" Range("E3").AutoFill Range("E3:E" & finalRow) End Sub Sub componentDamaged() finalRow = Range("K3").SpecialCells(xlCellTypeLastCell).Row Range("T3").Formula = "=IF(OR(S3 <> 0, (R3 <> 0)), S3/R3,0)" Range("T3").AutoFill Range("T3:T" & finalRow)	Column D refers Features Crossed Column S refers to ΣLocal SI*Relative Weights Column R refers to ΣRelative Element Weights Column K refers to On System Asset Code Column Q refers to Unique Asset Codes Column O refers to Relative Element Weight

End Sub Sub sumOfRelativeWeights() finalRow = Range("K3").SpecialCells(xlCellTypeLastCell).Row finalRowUnique = Range("Q3").SpecialCells(xlCellTypeLastCell).Row Range("R3").Formula = "=SUMIF(K3:K" & finalRow & ",Q3,O3:O" & finalRow & ")" Range("R3").AutoFill Range("R3:R" & finalRow) End Sub Sub CopyLocalSIandAssetCode() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Severity Index") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("EROR") '1. Find last used row in the copy range based on data in column A lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "I").End(xlUp).Row '2. Copy & Paste Data	

``
  wsCopy.Range("I2:I" & lCopyLastRow).Copy
  wsDest.Range("K3").PasteSpecial xlPasteValues
  wsCopy.Range("J2:J" & lCopyLastRow).Copy
  wsDest.Range("L3").PasteSpecial xlPasteValues
  wsCopy.Range("A2:A" & lCopyLastRow).Copy
  wsDest.Range("M3").PasteSpecial xlPasteValues
  wsCopy.Range("K2:K" & lCopyLastRow).Copy
  wsDest.Range("Q3").PasteSpecial xlPasteValues
 	
 Application.DisplayAlerts = True
 	
End Sub
 	
Sub normalizeOnSystemAssetCodes()
finalRow = Range("K3").SpecialCells(xlCellTypeLastCell).Row
    'For Each cell In Worksheets("EROR").Range("K3:K" & finalRow).Cells
 	
      ' cell.Value = cell.Value
 	
   ' Next
    Range("K3").Select
    Range(Selection, Selection.End(xlDown)).Select
    Selection.NumberFormat = "0.00"
    Selection.NumberFormat = "0.0"
    Selection.NumberFormat = "0"
End Sub
 	
Sub elementsCrossed()
``
	Column M refers to Element

finalRow = Range("K3").SpecialCells(xlCellTypeLastCell).Row Range("N3").Formula = "=IF(OR(COUNTIF(M3,""*Deck*""),COUNTIF(M3,""*Flange*""),COUNTIF(M3,""*Slab*""),COUNTIF(M3,""*Conventionally Formed*""),COUNTIF(M3,""*Concrete Panels*"")),""Decks"",IF(OR(COUNTIF(M3,""*Girder*""),COUNTIF(M3,""*Beam*""),COUNTIF(M3,""*Closed Web*""),COUNTIF(M3,""*Stringer*""),COUNTIF(M3,""*Truss*""),COUNTIF(M3,""*Arch*""),COUNTIF(M3,""*Cable*""),COUNTIF(M3,""*Cable*""),COUNTIF(M3,""*Gusset Plate*""),COUNTIF(M3,""*Pin*"")),""Superstructure""," & _ "IF(OR(COUNTIF(M3,""*Column*""),COUNTIF(M3,""*Secondary Members*""),COUNTIF(M3,""*Wing Wall*""),COUNTIF(M3,""*Rip Rap*""),COUNTIF(M3,""*Retaining Wall*""),COUNTIF(M3,""*Web Wall*""),COUNTIF(M3,""*Spread Footing*""),COUNTIF(M3,""*Column Tower*""),COUNTIF(M3,""*Trestle*""),COUNTIF(M3,""*Pile*""),COUNTIF(M3,""*Pier*""),COUNTIF(M3,""*Abutment*"")),""Substructure"",IF(OR(COUNTIF(M3,""*Culvert*"")),""Culvert"",IF(OR(COUNTIF(M3,""*Joint*""),COUNTIF(M3,""*Seal*"")," & _ "COUNTIF(M3,""*Modular*"")),""Joints"",IF(OR(COUNTIF(M3,""*Approach Slab*"")),""Approach Slabs"",IF(OR(COUNTIF(M3,""*Wearing	

Surfaces*""),COUNTIF(M3,""*Overlay*""),COUNTIF(	
M3,""*Surface Treatment*"")),""Wea" & _	
"ring Surfaces"",IF(OR(COUNTIF(M3,""*Steel	Column N refers to Element Type
Protective Coating*""),COUNTIF(M3,""*Concrete	
Protective Coating*""),COUNTIF(M3,""*Protective	
Coatings*"")),""Protective	
Coatings"",IF(OR(COUNTIF(M3,""*Concrete	
Reinforcing Steel Protective System*"")),""Concrete	
Reinforcing Steel Protective	
System"",IF(OR(COUNTIF(M3,""*Bearing*"")),""Beari	
ngs"",IF(OR(COUNTIF(M3,""*Railing*""),COUNTIF(	
M3,""*Rail*"")),""Railings"","""")))))))))))"	
Range("N3").AutoFill Range("N3:N" & finalRow)	
End Sub	
Sub RelativeElementWeight()	
finalRow =	Column L refers to Local SI
Range("K3").SpecialCells(xlCellTypeLastCell).Row	Column O refers to Relative Element
Range("O3").Formula =	Weight
"=IF(N3=""Substructure"",$B$4,IF(N3=""Superstructure	
"",$B$3,IF(N3=""Decks"",$B$5,IF(N3=""Slabs"",$B$5,I	
F(N3=""Culvert"",$B$6,IF(N3=""Bearings"",$B$7,IF(N	
3=""Joints"",$B$8,IF(N3=""Railings"",$B$9,IF(N3=""	Column K refers to On System Asset
Wearing Surfaces"",$B$10,IF(N3=""Protective	Code
Coatings"",$B$10,IF(N3=""Concrete Reinforcing Steel	Column Q refers to Unique Asset Codes
Protective System"",$B$10,IF(N3=""Approach	Column P refers to Local SI*Relative
Slabs"",$B$11,0))))))))))))"	Weights
Range("O3").AutoFill Range("O3:O" & finalRow)	
End Sub	
Sub localSIAndRelativeWeights()	

finalRow =	
Range("K3").SpecialCells(xlCellTypeLastCell).Row	Column E refers to Feature Index
Range("P3").Formula = "=L3*O3"	Column G refers to BRDG_ID
Range("P3").AutoFill Range("P3:P" & finalRow)	
End Sub	
Sub summationOfLocalSIandRelativeWeights()	
finalRow =	
Range("K3").SpecialCells(xlCellTypeLastCell).Row	
Range("S3").Formula = "=SUMIF(K3:K" & finalRow &	
",Q3,P3:P" & finalRow & ")"	Column T refers to Component Damaged
Range("S3").AutoFill Range("S3:S" & finalRow)	Column U refers to Features Crossed
End Sub	
Sub finalFeatureCrossed()	
finalRow =	
Range("G3").SpecialCells(xlCellTypeLastCell).Row	
finalRowUnique =	
Range("Q3").SpecialCells(xlCellTypeLastCell).Row	
Range("U3").Formula = "=INDEX($E$3:E" &	
finalRow & ", MATCH(Q3,$G$3:G" & finalRow &	
",0))"	
Range("U3").AutoFill Range("U3:U" &	
finalRowUnique)	
End Sub	
Sub ERORIndex()	
finalRow =	
Range("G3").SpecialCells(xlCellTypeLastCell).Row	
finalRowUnique =	
Range("Q3").SpecialCells(xlCellTypeLastCell).Row	
Range("V3").Formula = "=0.5*T3+0.5*U3"	
Range("V3").AutoFill Range("V3:V" &	
finalRowUnique)	

End Sub
Sub convertToDecimals()
finalRow =
Range("G3").SpecialCells(xlCellTypeLastCell).Row
Dim rng As Range
  Set rng = Range("L3:L" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("O3:O" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("P3:P" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("R3:R" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("S3:S" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("T3:T" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("U3:U" & finalRow)
  rng.NumberFormat = "0.00"
  Set rng = Range("V3:V" & finalRow)
  rng.NumberFormat = "0.00"
  End Sub	

3.1.7 Geometry Factor Code	Comments
Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet	

Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("TxDOT Open Data Portal Data") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Geometry Factor") '1. Find last used row in the copy range based on data in column A lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "D").End(xlUp).Row '2. Copy & Paste Data wsCopy.Range("D2:D" & lCopyLastRow).Copy wsDest.Range("A3").PasteSpecial xlPasteValues wsCopy.Range("CV2:CV" & lCopyLastRow).Copy wsDest.Range("B3").PasteSpecial xlPasteValues wsCopy.Range("DF2:DF" & lCopyLastRow).Copy wsDest.Range("D3").PasteSpecial xlPasteValues wsCopy.Range("DG2:DG" & lCopyLastRow).Copy wsDest.Range("F3").PasteSpecial xlPasteValues wsCopy.Range("DH2:DH" & lCopyLastRow).Copy wsDest.Range("H3").PasteSpecial xlPasteValues wsCopy.Range("DJ2:DJ" & lCopyLastRow).Copy wsDest.Range("J3").PasteSpecial xlPasteValues wsCopy.Range("DK2:DK" & lCopyLastRow).Copy wsDest.Range("L3").PasteSpecial xlPasteValues	

wsCopy.Range("CZ2:CZ" & lCopyLastRow).Copy wsDest.Range("O3").PasteSpecial xlPasteValues wsCopy.Range("CN2:CN" & lCopyLastRow).Copy wsDest.Range("P3").PasteSpecial xlPasteValues wsCopy.Range("AS2:AS" & lCopyLastRow).Copy wsDest.Range("Q3").PasteSpecial xlPasteValues wsCopy.Range("AN2:AN" & lCopyLastRow).Copy wsDest.Range("S3").PasteSpecial xlPasteValues wsCopy.Range("L2:L" & lCopyLastRow).Copy wsDest.Range("W3").PasteSpecial xlPasteValues wsCopy.Range("GE2:GE" & lCopyLastRow).Copy wsDest.Range("X3").PasteSpecial xlPasteValues wsCopy.Range("AP2:AP" & lCopyLastRow).Copy wsDest.Range("Y3").PasteSpecial xlPasteValues wsCopy.Range("EL2:EL" & lCopyLastRow).Copy wsDest.Range("AC3").PasteSpecial xlPasteValues wsCopy.Range("CP2:CP" & lCopyLastRow).Copy wsDest.Range("AD3").PasteSpecial xlPasteValues Application.DisplayAlerts = True End Sub Sub normalizeBridgeID() With Sheets("Geometry Factor") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With For Each cell In Worksheets("Age Factor").Range("A3:A" & finalRow).Cells cell.Value = cell.Value	

Next Range("A3").Select Range(Selection, Selection.End(xlDown)).Select Selection.NumberFormat = "0.00" Selection.NumberFormat = "0.0" Selection.NumberFormat = "0" End Sub Sub calculateA() 'Calculating A With Sheets("Geometry Factor") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("C3").Formula = "=IF(B3 <= 3, 1, IF(B3 = 4, 0.6,IF(B3 = 5, 0.2, IF(B3 >= 6, 0,IF(B3 = ""N"", 0, 0)))))" Range("C3").AutoFill Range("C3:C" & finalRow) End Sub Sub calculateB() 'Calculating B With Sheets("Geometry Factor") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("E3").Formula = "=IF(D3 <= 3, 1, IF(D3 = 4, 0.6,IF(B3 = 5, 0.2, IF(D3 >= 6, 0,IF(D3 = ""N"", 0, 0)))))" Range("E3").AutoFill Range("E3:E" & finalRow) End Sub	Column B refers to DECK_COND_RTNG Column D refers to APPRSL_RTNG_STRUC_EVAL Column B refers to DECK_COND_RTNG

Sub calculateC()	
'Calculating C	
With Sheets("Geometry Factor")	
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
Range("G3").Formula = "=IF(F3 <= 3, 1, IF(F3 = 4,	Column F refers to
0.5,IF(F3 = 5, 0.25, IF(F3 >= 6, 0,IF(F3 = ""N"", 0,	APPRSL_RTNG_DECK_GMTRY
0)))))"	
Range("G3").AutoFill Range("G3:G" & finalRow)	
End Sub	
Sub calculateD()	
'Calculating D	
With Sheets("Geometry Factor")	
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
Range("I3").Formula = "=IF(H3 <= 3, 1, IF(H3 = 4,	Column H refers to
0.5,IF(H3 = 5, 0.25, IF(H3 >= 6, 0,IF(H3 = ""N"", 0,	APPRSL_RTNG_VERT_HRZNTL_UN
0)))))"	DR
Range("I3").AutoFill Range("I3:I" & finalRow)	
End Sub	
Sub calculateE()	
'Calculating E	
With Sheets("Geometry Factor")	
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
Range("K3").Formula = "=IF(J3 <= 3, 1, IF(J3 = 4,	
0.5,IF(J3 = 5, 0.25 ,IF(J3 >= 6, 0,IF(J3 = ""N"", 0, 0)))))"	Column J refers to
Range("K3").AutoFill Range("K3:K" & finalRow)	APPRSL_RTNG_WATRWY

End Sub	
Sub calculateF()	
'Calculating F	
With Sheets("Geometry Factor")	
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
Range("M3").Formula = "=IF(L3 <= 3, 1, IF(L3 = 4, 0.5,	
IF(L3 = 5, 0.25, IF(L3 >= 6, 0,IF(L3 = ""N"", 0, 0)))))"	
Range("M3").AutoFill Range("M3:M" & finalRow)	Column L refers to
End Sub	APPRSL_RTNG_APRCH_ALGN
Sub calculateRatingReduction()	
With Sheets("Geometry Factor")	
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
Range("N3").Formula = "=(C3+E3+G3+I3+K3+M3)/6"	
Range("N3").AutoFill Range("N3:N" & finalRow)	
End Sub	Column C refers to A
Sub calculateG()	Column E refers to B
'Calculate G	Column G refers to C
With Sheets("Geometry Factor")	Column I refers to D
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	Column K refers to E
End With	Column M refers to F
For i = finalRow To 3 Step -1	
If Range("O" & i).Value <> "N" Then	
If Range("P" & i).Value + 2 < Range("Q" &	
i).Value Then	
Range("R" & i) = 1	

ElseIf Range("P" & i).Value + 2 >= Range("Q" & i).Value Then
Range("R" & i) = 0
 	
End If
Else
Range("R" & i) = ""
End If
Next i
End Sub
Sub calculateY()
'Calculating Y
With Sheets("Geometry Factor")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	

End With Range("T3").Formula = "=P3/S3" Range("T3").AutoFill Range("T3:T" & finalRow) End Sub Sub calculateX() 'Calculating X With Sheets("Geometry Factor") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With	Column P refers to BRDG_RDWAY_WIDTH_CURB_CURB Column S refers to LANES_ON_STRUC
Range("Z3").Formula = "=IF(X3 = 1, Y3/S3, IF(X3 = 2, Y3/S3, IF(X3 = 8, Y3/S3, IF(X3 = """", Y3/S3,""""))))" Range("Z3").AutoFill Range("Z3:Z" & finalRow) End Sub Sub combineH() 'Combining H With Sheets("Geometry Factor") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	Column X refers to INT_RTE_DSGNT_SRVC_LVL Column Y refers to ADT Column S refers to LANES_ON_STRUC

End With	
For i = finalRow To 3 Step -1	
If IsEmpty(Range("U" & i).Value) = True Then	
Range("AA" & i) = Range("V" & i).Value	
ElseIf IsEmpty(Range("V" & i).Value) = True Then	
Range("AA" & i) = Range("U" & i).Value	
End If	
Next i	
End Sub	
Sub calculateW()	
'Calculating W	
With Sheets("Geometry Factor")	
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	Column O refers to
Range("AB3").Formula = "=IF(O3 <> ""N"", AA3,	CULV_COND_RTNG
0.25*R3+0.75*AA3)"	Column AA refers to H (Combined)
Range("AB3").AutoFill Range("AB3:AB3" & finalRow)	Column R refers to G
End Sub	
Sub calculateV()	
'Calculating V	
With Sheets("Geometry Factor")	
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
For i = finalRow To 3 Step -1	
If Range("AC" & i).Value > 0 And Range("AD" &	
i).Value > 1600 Then	
Range("AE" & i) = 0	
ElseIf Range("AC" & i).Value > 0 And Range("AD" &	
i).Value < 1600 Then	

Range("AE" & i) = 1
ElseIf Range("AC" & i).Value = 0 And Range("AD" & i).Value > 1400 Then
Range("AE" & i) = 0
ElseIf Range("AC" & i).Value = 0 And Range("AD" & i).Value < 1400 Then
Range("AE" & i) = 1
End If
Next i
End Sub
Sub calculateGeometryIndex()
'Calculating GeometryIndex
With Sheets("Geometry Factor")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Range("AF3").Formula = "=0.45*N3+0.45*AB3+0.1*AE3"
Range("AF3").AutoFill Range("AF3:AF" & finalRow)
End Sub
Sub calculateHOneLane()
With Sheets("Geometry Factor")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
For i = finalRow To 3 Step -1
If Range("S" & i).Value = 1 Then
 	
If Range("T" & i).Value < 14 Then
Range("U" & i) = 1
 	
ElseIf Range("T" & i).Value >= 14 And Range("T" & i).Value < 18 Then
	Column N refers to Rating Reduction
	Column AB refers to W
	Column AE refers to V

Range("U" & i) = (0.25 * (18 - Range("T" & i).Value)) / 4
 	
ElseIf Range("T" & i).Value >= 18 Then
Range("U" & i) = 0
 	
End If
Else
Range("U" & i) = ""
End If
Next i
End Sub
Sub calculateHTwoLane()
With Sheets("Geometry Factor")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
For i = finalRow To 3 Step -1
 	
If Range("S" & i).Value = 2 And Range("T" & i).Value >= 16 Then
Range("V" & i) = 0
 	
ElseIf Range("S" & i).Value = 3 And Range("T" & i).Value >= 15 Then
Range("V" & i) = 0
 	
ElseIf Range("S" & i).Value = 4 And Range("T" & i).Value >= 14 Then
Range("V" & i) = 0	

ElseIf Range("S" & i).Value = 5 And Range("T" & i).Value >= 12 Then
Range("V" & i) = 0
 	
Else
Range("V" & i) = ""
 	
End If
 	
Next i
With Sheets("Geometry Factor")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
For i = finalRow To 3 Step -1
If IsEmpty(Range("V" & i).Value) = True Then
 	
If Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value <= 50 And Range("T" & i).Value < 9 Then
Range("V" & i) = 0.5
 	
ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value <= 50 And Range("T" & i).Value >= 9 Then
Range("V" & i) = 0
 	
ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value > 50 And	

```
Range("Z" & i).Value <= 125 And Range("T" & i).Value
>= 10 And Range("T" & i).Value < 13 Then
        Range("V" & i) = 0.33 * (13 - (Range("T" &
i).Value) / 3)

        ElseIf Range("S" & i).Value = 2 Or Range("S" &
i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S"
& i).Value = 5 And Range("Z" & i).Value > 50 And
Range("Z" & i).Value <= 125 And Range("T" & i).Value
>= 13 Then
        Range("V" & i) = 0

        ElseIf Range("S" & i).Value = 2 Or Range("S" &
i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S"
& i).Value = 5 And Range("Z" & i).Value > 125 And
Range("Z" & i).Value <= 375 And Range("T" & i).Value
< 11 Then
        Range("V" & i) = 1

        ElseIf Range("S" & i).Value = 2 Or Range("S" &
i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S"
& i).Value = 5 And Range("Z" & i).Value > 125 And
Range("Z" & i).Value <= 375 And Range("T" & i).Value
>= 11 And Range("T" & i).Value < 14 Then
        Range("V" & i) = 0.33 * (14 - (Range("T" &
i).Value) / 3)

        ElseIf Range("S" & i).Value = 2 Or Range("S" &
i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S"
& i).Value = 5 And Range("Z" & i).Value > 125 And
```

Range("Z" & i).Value <= 375 And Range("T" & i).Value >= 14 Then Range("V" & i) = 0 ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 Or Range("S" & i).Value = 5 And Range("Z" & i).Value > 375 And Range("Z" & i).Value <= 1350 And Range("T" & i).Value < 12 Then Range("V" & i) = 1 ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value > 375 And Range("Z" & i).Value <= 1350 And Range("T" & i).Value >= 12 And Range("T" & i).Value < 16 Then Range("V" & i) = 0.25 * (16 - (Range("T" & i).Value) / 4) ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value > 375 And Range("Z" & i).Value <= 1350 And Range("T" & i).Value >= 16 Then Range("V" & i) = 0 ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value > 1350 And Range("T" & i).Value < 15 Then Range("V" & i) = 1	

```
        ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value > 1350 And Range("T" & i).Value >= 15 And Range("T" & i).Value < 16 Then
        Range("V" & i) = 1 * (16 - Range("T" & i).Value)

        ElseIf Range("S" & i).Value = 2 Or Range("S" & i).Value = 3 Or Range("S" & i).Value = 4 Or Range("S" & i).Value = 5 And Range("Z" & i).Value > 1350 And Range("T" & i).Value >= 16 Then
        Range("V" & i) = 0

        Else
        Range("V" & i) = ""

        End If
    End If

Next i

End Sub
Sub deleteYwithError()
Dim i As Long, finalRow As Long
With Sheets("Geometry Factor")
  finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
   For i = finalRow To 3 Step -1
   If IsEmpty(Range("P" & i).Value) = True Then
```

```
        Range("P" & i).EntireRow.Delete
    End If
    Next i
End Sub
Sub allInOneFileGeometry()
With Sheets("Geometry Factor")
  finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
LoadingScreen.Show vbModeless
DoEvents
Range("A3:AF" & finalRow & "").Clear
copyFromMainFile
'normalizeBridgeID
convertToText
 calculateA
 calculateB
 calculateC
 calculateD
 calculateE
 calculateF
 calculateRatingReduction
 calculateG
 calculateY
 deleteYwithError
 calculateX
 calculateHOneLane
 calculateHTwoLane
 combineH
 calculateW
 calculateV
 calculateGeometryIndex
```

convertToDecimals Unload LoadingScreen End Sub Sub convertToText() With Sheets("Geometry Factor") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Dim rng As Range Set rng = Range("O3:O" & finalRow) rng.NumberFormat = "@" End Sub Sub convertToDecimals() With Sheets("Geometry Factor") finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Dim rng As Range Set rng = Range("C3:C" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("E3:E" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("G3:G" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("I3:I" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("K3:K" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("M3:M" & finalRow) rng.NumberFormat = "0.00" Set rng = Range("N3:N" & finalRow) rng.NumberFormat = "0.00"	

Set rng = Range("R3:R" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("T3:T" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("U3:U" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("V3:V" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("Z3:Z" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("AA3:AA" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("AB3:AB" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("AE3:AE" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("AF3:AF" & finalRow)
rng.NumberFormat = "0.00"
End Sub
Sub timeFrame(pauseTime As Double)
Start = Timer
Do
DoEvents
Loop Until (Timer - Start) >= pauseTime
End Sub
Sub DropDown()
If Sheet13.Shapes("DropDownButton").Visible Then
Sheet13.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet13.Shapes("DropDownButton").Visible = msoTrue
End If	

End Sub
Sub HideAndShowRatingReductionValues()
If Sheet13.Shapes("RatingReduction").Visible Then
Sheet13.Shapes("RatingReduction").Visible = msoFalse
Else
Sheet13.Shapes("RatingReduction").Visible = msoTrue
End If
End Sub
Sub HideAndShowGeometryIndexFormula()
If Sheet13.Shapes("GeometryIndexFormula").Visible Then
Sheet13.Shapes("GeometryIndexFormula").Visible = msoFalse
Else
Sheet13.Shapes("GeometryIndexFormula").Visible = msoTrue
End If
End Sub
Sub HideAndShowRoadwayWidthInsufficiency()
If Sheet13.Shapes("RoadwayWidthInsufficiency").Visible Then
Sheet13.Shapes("RoadwayWidthInsufficiency").Visible = msoFalse
Else
Sheet13.Shapes("RoadwayWidthInsufficiency").Visible = msoTrue
End If
End Sub
Sub HideAndShowVerticalClearanceInsufficiencyValues()	

If
Sheet13.Shapes("VerticalClearanceInsufficiencyValues")
.Visible Then
Sheet13.Shapes("VerticalClearanceInsufficiencyValues")
.Visible = msoFalse
Else
Sheet13.Shapes("VerticalClearanceInsufficiencyValues")
.Visible = msoTrue
End If
End Sub	

3.1.8 Severity Index Code	Comments
Sub getDatafromAllData() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long 'Set variables for copy and destination sheets Set wsCopy = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Elemental Data (AssetWise)") Set wsDest = Workbooks("BridgeRep 1.0.xlsm").Worksheets("Severity Index")	

```
  '1. Find last used row in the copy range based on data in column A
  lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count, "B").End(xlUp).Row

  '2. Copy & Paste Data
  wsCopy.Range("D2:D" & lCopyLastRow).Copy
  wsDest.Range("A2").PasteSpecial xlPasteValues
  wsCopy.Range("E2:E" & lCopyLastRow).Copy
  wsDest.Range("B2").PasteSpecial xlPasteValues
  wsCopy.Range("F2:F" & lCopyLastRow).Copy
  wsDest.Range("C2").PasteSpecial xlPasteValues
   wsCopy.Range("G2:G" & lCopyLastRow).Copy
  wsDest.Range("D2").PasteSpecial xlPasteValues
   wsCopy.Range("H2:H" & lCopyLastRow).Copy
  wsDest.Range("E2").PasteSpecial xlPasteValues
   wsCopy.Range("I2:I" & lCopyLastRow).Copy
  wsDest.Range("F2").PasteSpecial xlPasteValues
 wsCopy.Range("J2:J" & lCopyLastRow).Copy
  wsDest.Range("G2").PasteSpecial xlPasteValues
wsCopy.Range("K2:K" & lCopyLastRow).Copy
  wsDest.Range("H2").PasteSpecial xlPasteValues
wsCopy.Range("L2:L" & lCopyLastRow).Copy
  wsDest.Range("I2").PasteSpecial xlPasteValues
 Application.DisplayAlerts = True

End Sub

Sub removeQuantity()
 Dim i As Long, finalRow As Long
```

finalRow =
Range("I2").SpecialCells(xlCellTypeLastCell).Row
For i = finalRow To 2 Step -1
If Range("C" & i).Value = 0 Then
Range("C" & i).EntireRow.Delete
End If
Next i
End Sub
Sub calculateLocalSI()
" Calculating the Q
With Sheets("Severity Index")
lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Range("J2").Formula =
"=(0*E2+0.33*F2+0.67*G2+1*H2)/C2"
Range("J2").AutoFill Range("J2:J" & lastRow)
End Sub
Sub removeDuplicateAssetCodes()
" Copy pasting the asset codes and removing duplicates
Range("I2").Select
Range(Selection, Selection.End(xlDown)).Select
Selection.Copy
Range("K2").Select
ActiveSheet.Paste
Application.CutCopyMode = False
Columns("K:K").Select
 	
ActiveSheet.Range("$K$1:$K$40898").RemoveDuplicates Columns:=1, Header:= _
xlNo
	Column E refers to Condition State 1
	Column F refers to Condition State 2
	Column G refers to Condition State 3
	Column H refers to Condition State 4
	Column C refers to Total Quantity

With Range("K2:K" & Cells(Rows.Count, 1).End(xlUp).Row)
.NumberFormat = "General"
.Value = .Value
.NumberFormat = "0"
End With
End Sub
Sub RemoveDefects()
Dim i As Long, finalRow As Long
With Sheets("Severity Index")
lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
defectsList = Sheets("DefectsList").Cells(Rows.Count, 1).End(xlUp).Row
For i = lastRow To 2 Step -1
For j = defectsList To 2 Step -1
If Range("A" & i).Value Like "*" & Sheets("DefectsList").Range("A" & j).Value & "*" Then
Range("A" & i).EntireRow.Delete
End If
Next j
Next i
End Sub
Sub calculateImportanceWeights()
With Sheets("Severity Index")
lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Range("L2").Formula = "=IF(OR(COUNTIF(A2,""*Reinforced Concrete Deck*""),COUNTIF(A2,""*Flange*""),COUNTIF(A2,""*Steel Deck – Open Grid*""),COUNTIF(A2,""*Steel
	Column A refers to Element

Deck – Concrete Filled Grid*""),COUNTIF(A2,""*Steel Deck – Corrugated/Orthotropic/Etc.*""),COUNTIF(A2,""*Timber Deck*""),COUNTIF(A2,""*Timber Slab*""),COUNTIF(A2,""*Other Material Deck*""),COUNTIF(A2,""*Deck*""),COUNTIF(A2,""*Other Material Slab*""),COUNTIF(A2,""*Girder*""),COUNTIF(A2,""*Beam*""),COUNTIF(A2,""*Box Girder*""),COUNTIF(A2,""*Closed Web*""),COUNTIF(A2,""*Stringer*""),COUNTIF(A2,""*Truss*""),COUNTIF(A2,""*Arch*""),COUNTIF(A2,""*Floor Beam*""),COUNTIF(A2,""*Cable - Primary*""),COUNTIF(A2,""*Cable - Secondary*""),COUNTIF(A2,""*Gusset Plate*""),COUNTIF(A2,""*Pin*""),COUNTIF(A2,""*Pin and Hanger Assembly*""),COUNTIF(A2,""*Web Wall*""),COUNTIF(A2,""*Column*""),COUNTIF(A2,""*Column Tower*""),COUNTIF(A2,""*Trestle*""),COUNTIF(A2,""*Pier Wall*"")," & _ "COUNTIF(A2,""*Abutment*""),COUNTIF(A2,""*Pile*""),COUNTIF(A2,""*Pier*""),COUNTIF(A2,""*Conventionally Formed*""),COUNTIF(A2,""*Culvert*""),COUNTIF(A2,""*Retaining Wall*""),COUNTIF(A2,""*Retaining Wall Slab*""),COUNTIF(A2,""*Reinforced Concrete Slab*""),COUNTIF(A2,""*Rip Rap*""),COUNTIF(A2,""*Concrete Panels*""),COUNTIF(A2,""*Footing*""),COUNTIF(A2,""*Secondary Members*""),COUNTIF(A2,""*Wing	

Wall*"")),0.24,IF(OR(COUNTIF(A2,""*Strip Seal	
Expansion Joint*""),COUNTIF(A2,""*Pourable Joint	
Seal*"")," & _	
"COUNTIF(A2,""*Strip Seal Expansion	
Joint*""),COUNTIF(A2,""*Compression Join	
Seal*""),COUNTIF(A2,""*Assembly	
Joint*""),COUNTIF(A2,""*Assembly	
Seal*""),COUNTIF(A2,""*Open Expansion	
Joint*""),COUNTIF(A2,""*Assembly Joint without	
Seal*""),COUNTIF(A2,""*Other	
Joint*""),COUNTIF(A2,""*Joint*"")),0.08,IF(OR(COU	
NTIF(A2,""*Wearing	
Surfaces*""),COUNTIF(A2,""*Protective	
Coating*""),COUNTIF(A2,""*Concrete Reinforcing	
Steel Protective System*"")," & _	
"COUNTIF(A2,""*Surface	
Treatment*""),COUNTIF(A2,""*Protective	
Coatings*""),COUNTIF(A2,""*Concrete Reinforcing	
Steel Protective	
System*""),COUNTIF(A2,""*Overlay*"")),0.03,If(Or(C	
OUNTIF(A2,""*Bearing*""),COUNTIF(A2,""*Bearings	Column J refers to Local SI
*"")),0.1,If(OR(COUNTIF(A2,""*Railings*""),COUNTI	Column L refers to Importance Weights
F(A2,""*Railing*""),COUNTIF(A2,""*Rail*"")),0.05,IF(	
OR(COUNTIF(A2,""*Approach	
Slabs*""),COUNTIF(A2,""*Reinforced Concrete	
Approach Slab*""),COUNTIF(A2,""*Prestressed	
Concrete Approach Slab*"")),0.02,0))))))"	
Range("L2").AutoFill Range("L2:L" & lastRow)	Column K refers to Unique Asset Codes
End Sub	Column L refers to Importance Weights
Sub localSIandImportanceWeights()	Column I refers to Elemental Data Asset
With Sheets("Severity Index")	Code

lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("M2").Formula = "=PRODUCT(J2,L2)" Range("M2").AutoFill Range("M2:M" & lastRow) End Sub	
Sub sumOfImportanceWeights() With Sheets("Severity Index") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("N2").Formula = "=SUMIF(I2:I" & lastRow & ",K2,L2:L" & lastRow & ")" Range("N2").AutoFill Range("N2:N" & lastRow) End Sub	Column I refers to Elemental Data Asset Code Column K refers to Unique Asset Codes Column M refers to Local SI*Importance Weights
Sub sumOfLocalSIandImportance() With Sheets("Severity Index") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("O2").Formula = "=SUMIF(I2:I" & lastRow & ",K2,M2:M" & lastRow & ")" Range("O2").AutoFill Range("O2:O" & lastRow) End Sub	Column O refers to Σ Local SI*Importance Weights Column N refers to Σ Importance Weights
Sub BridgeSI() With Sheets("Severity Index") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("P2").Formula = "=O2/N2" Range("P2").AutoFill Range("P2:P" & lastRow) End Sub Sub allInUpdate() With Sheets("Severity Index")	

```
  lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Load LoadingScreen
LoadingScreen.Show vbModeless
DoEvents
Range("A2:P" & lastRow & "").Clear
getDatafromAllData
removeQuantity
calculateLocalSI
RemoveDefects
removeDuplicateAssetCodes
calculateImportanceWeights
localSIandImportanceWeights
sumOfImportanceWeights
sumOfLocalSIandImportance
BridgeSI

Unload LoadingScreen
End Sub

Sub DropDown()
If Sheet24.Shapes("DropDownButton").Visible Then
Sheet24.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet24.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub
Sub HideAndShowIndexScoreFormula()
If Sheet24.Shapes("IndexScoreFormula").Visible Then
Sheet24.Shapes("IndexScoreFormula").Visible =
msoFalse
```

Else
Sheet24.Shapes("IndexScoreFormula").Visible =
msoTrue
End If
End Sub
Sub convertToDecimals()
With Sheets("Severity Index")
finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Dim rng As Range
Set rng = Range("J3:J" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("L3:L" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("M3:M" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("N3:N" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("O3:O" & finalRow)
rng.NumberFormat = "0.00"
Set rng = Range("P3:P" & finalRow)
rng.NumberFormat = "0.00"
 	
End Sub	

3.1.9 Cost Factor Code	Comments
Sub copyFromMainFile() Application.ScreenUpdating = False Application.DisplayAlerts = False Dim wsCopy As Worksheet Dim wsDest As Worksheet Dim lCopyLastRow As Long Dim lDestLastRow As Long	

```
  'Set variables for copy and destination sheets
  Set wsCopy = Workbooks("BridgeRep
1.0.xlsm").Worksheets("Severity Index")
  Set wsDest = Workbooks("BridgeRep
1.0.xlsm").Worksheets("Cost Factor")

  '1. Find last used row in the copy range based on data in
column A
  lCopyLastRow = wsCopy.Cells(wsCopy.Rows.Count,
"D").End(xlUp).Row

  '2. Copy & Paste Data
  wsCopy.Range("I2:I" & lCopyLastRow).Copy
  wsDest.Range("A3").PasteSpecial xlPasteValues
  wsCopy.Range("A2:A" & lCopyLastRow).Copy
  wsDest.Range("B3").PasteSpecial xlPasteValues
  wsCopy.Range("B2:B" & lCopyLastRow).Copy
  wsDest.Range("C3").PasteSpecial xlPasteValues
   wsCopy.Range("C2:C" & lCopyLastRow).Copy
  wsDest.Range("D3").PasteSpecial xlPasteValues
   wsCopy.Range("D2:D" & lCopyLastRow).Copy
  wsDest.Range("E3").PasteSpecial xlPasteValues
   wsCopy.Range("E2:E" & lCopyLastRow).Copy
  wsDest.Range("F3").PasteSpecial xlPasteValues
 wsCopy.Range("F2:F" & lCopyLastRow).Copy
  wsDest.Range("G3").PasteSpecial xlPasteValues
 wsCopy.Range("G2:G" & lCopyLastRow).Copy
  wsDest.Range("H3").PasteSpecial xlPasteValues
   wsCopy.Range("H2:H" & lCopyLastRow).Copy
  wsDest.Range("I3").PasteSpecial xlPasteValues
```

wsCopy.Range("J2:J" & lCopyLastRow).Copy	
wsDest.Range("J3").PasteSpecial xlPasteValues	
wsCopy.Range("K2:K" & lCopyLastRow).Copy	
wsDest.Range("O3").PasteSpecial xlPasteValues	
Range("O3").Select	
Range(Selection, Selection.End(xlDown)).Select	
Selection.NumberFormat = "0.00"	
Selection.NumberFormat = "0.0"	
Selection.NumberFormat = "0"	
Application.DisplayAlerts = True	
End Sub	
Sub costOfRepairAndState()	
With Sheets("Cost Factor")	
lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
Range("M3").Formula =	Column J refers to Local SI
"=IF(AND(J3>=0.33,J3<=0.67),(K3*(G3+H3+I3)),IF(J3	Column K refers to Cost of Repair
>0.67,N3,""""))"	Column G refers to State 2
Range("M3").AutoFill Range("M3:M" & lastRow)	Column H refers to State 3
End Sub	Column I refers to State 4
Sub costOfReplaceAndTotalQuantity()	Column N refers to Cost Of
With Sheets("Cost Factor")	Replacement*Total Quantity
lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row	
End With	
Range("N3").Formula = "=IF(J3>=0.33, L3*D3,"""")"	
Range("N3").AutoFill Range("N3:N" & lastRow)	Column J refers to Local SI
	Column L refers to Cost of Replacement
End Sub	Column D refers to Total Quantity
Sub summationCostOfRepairAndState()	

With Sheets("Cost Factor") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("P3").Formula = "=SUMIF($A$3:A" & lastRow & ",O3,$M$3:M" & lastRow & ")" Range("P3").AutoFill Range("P3:P" & lastRow) End Sub	Column A refers to On System Asset Code Column O refers to Unique Asset Codes Column M refers to Cost Of Repair*(State2+State3+State4)
Sub summationCostOfReplaceAndTotalQuantity() With Sheets("Cost Factor") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("Q3").Formula = "=SUMIF(A3:A" & lastRow & ",O3, N3:N" & lastRow & ")" Range("Q3").AutoFill Range("Q3:Q" & lastRow) End Sub	Column O refers to Unique Asset Codes Column N refers to Cost Of Replacement*Total Quantity
Sub costIndex() With Sheets("Cost Factor") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With Range("R3").Formula = "=IFERROR(P3/Q3,0)" Range("R3").AutoFill Range("R3:R" & lastRow) End Sub	Column P refers to ∑ Cost Of Repair*Total Quantity Column Q refers to ∑ Cost Of Replacement*Total Quantity
Sub allInOneCostFactor() With Sheets("Cost Factor") lastRow = .Cells(.Rows.Count, 1).End(xlUp).Row End With LoadingScreen.Show vbModeless DoEvents Range("A3:R" & lastRow & "").Clear copyFromMainFile	

```
costOfReplaceAndTotalQuantity
costOfRepairAndState
summationCostOfRepairAndState
summationCostOfReplaceAndTotalQuantity
costIndex
convertToDecimals
Unload LoadingScreen
End Sub
Sub DropDown()
If Sheet11.Shapes("DropDownButton").Visible Then
Sheet11.Shapes("DropDownButton").Visible = msoFalse
Else
Sheet11.Shapes("DropDownButton").Visible = msoTrue
End If
End Sub
Sub HideAndShowHeatGraph()
If Sheet11.Shapes("HeatGraph").Visible Then
Sheet11.Shapes("HeatGraph").Visible = msoFalse
Else
Sheet11.Shapes("HeatGraph").Visible = msoTrue
End If
End Sub
Sub convertToDecimals()
   With Sheets("Cost Factor")
  finalRow = .Cells(.Rows.Count, 1).End(xlUp).Row
End With
Dim rng As Range
  Set rng = Range("R3:R" & finalRow)
  rng.NumberFormat = "0.00"


End Sub
```