Bridge Deficiency Metric Refinement: Longer Term Planning for State- and Locally-Owned Bridges

By

Dr. David P. Hale
Department of Information Systems, Statistics, and Management Science
The University of Alabama
Tuscaloosa, AL

Dr. J. Brandon Haynie
Aging Infrastructure Systems Center of Excellence
The University of Alabama
Tuscaloosa

and

Dr. Daniel Turner and Dr. James Richardson
Department of Civil, Construction, and Environmental Engineering
The University of Alabama
Tuscaloosa, AL

Prepared by

AISCE

Aging Infrastructure Systems Center of Excellence
The University of Alabama

UTCA

University Transportation Center for Alabama
The University of Alabama, The University of Alabama in Birmingham, and
The University of Alabama at Huntsville

ALDOT Report Number 930-742
AISCE Report Number 10-401
UTCA Report Number 08404
June 2010

UTCA Theme: Management and Safety of Transportation Systems

Bridge Deficiency Metric Refinement: Longer Term Planning for State- and Locally-Owned Bridges

By

Dr. David P. Hale
Department of Information Systems, Statistics, and Management Science
The University of Alabama
Tuscaloosa, AL

Dr. J. Brandon Haynie
Aging Infrastructure Systems Center of Excellence
The University of Alabama
Tuscaloosa

and

Dr. Daniel Turner and Dr. James Richardson
Department of Civil, Construction, and Environmental Engineering
The University of Alabama
Tuscaloosa, AL

Prepared by

AISCE

Aging Infrastructure Systems Center of Excellence
The University of Alabama

UTCA

University Transportation Center for Alabama
The University of Alabama, The University of Alabama in Birmingham, and
The University of Alabama at Huntsville

ALDOT Report Number 930-742
AISCE Report Number 10-401
UTCA Report Number 08404
June 2010

PREPARED WITH COOPERATION AND ASSISTANCE OF REPRESENTATIVES OF THE FOLLOWING AGENCIES AND ORGANIZATIONS

Alabama Department of Transportation, Federal Highway Administration-Alabama Division, and the following units of The University of Alabama: the Aging Infrastructure Systems Center of Excellence, the Manufacturing Information Technology Research Center, the University Transportation Center for Alabama, the Department of Civil, Construction and Environmental Engineering and the Area of Management Information Systems

The project associated with this report was funded wholly or in part by the Aging Infrastructure Systems Center of Excellence (AISCE), and the University Transportation Center for Alabama (UTCA). The contents of this project report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the U.S. Department of Transportation, University Transportation Centers Program, in the interest of information exchange. The U.S. Government, AISCE, UTCA, and the three universities comprising UTCA assume no liability for the contents or use thereof.

Technical Report Documentation Page

1. Report No. ALDOT 930-742	**2. Government Accession No.**	**3. Recipient Catalog No.**

4. Title and Subtitle: Bridge Deficiency Metric Refinement: Longer Term Planning for State- and Locally-Owned Bridges	**5. Report Date Submitted:** February 2010; Published June 2010 **6. Performing Organization Code**
7. Authors Drs. David Hale, Daniel Turner, James Richardson, Brandon Haynie	**8. Performing Organization Report No.** AISCE 10-401; UTCA #08404
9. Performing Organization Name & Address AISCE and UTCA The University of Alabama; P. O. Box 870205 Tuscaloosa, AL 35487-0208 205 348 5525; aisce@ua.edu	**10. Work Unit No.** **11. Contract or Grant No.**
12. Sponsoring Agency Name and Address Alabama Department of Transportation 1409 Coliseum Blvd Montgomery, AL 36110	**13. Type of Report and Period Covered** Final Report of Research Conducted from 2008-2009. **14. Sponsoring Agency Code**

15. Supplementary Notes

16. Abstract

The focus of this study was to devise a prioritization scheme for locally-owned bridges and to extend the planning time horizon for state-owned bridges. The inherent nature of the local and county structures prevents a direct application of the formulation described for the state solution. Consequently, a process to segregate structures based on capability and intended purpose was utilized. Each subgroup has a specific set of parameters that produces a more accurate assessment of the subgroups current condition with respect to deficiency. These subgroups are consolidated to a global deficiency list to present a single prioritized reference for all local and county structures.

The duplication of index values of multiple structures is addressed by defining a set of stringent filtering rules. This ensured that the prioritization of structures is based on their attributes instead of random positioning that occurs when ties are present. The filtering technique allows for the creation of a 5-7 year plan (250 structures) by validating the positions of structures that otherwise would be banded due to identical total scores. This single list consolidates requirements throughout the state and at all levels of utility to ensure an unbiased selection process can be executed.

17. Key Words Deficiency Algorithm, Bridge Management, Prioritization		**18. Distribution Statement**	
19. Security Class Unclassified	**20. Security Class**	**21. No of Pages** 51	**22. Price**

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

Contents

Contents ii
List of Tables v
List of Figures v
Executive Summary vi

1.0 Introduction 1
Goal For This Project 2

2.0 Comparison of State and Local Structure 3
Construction and Material Type 3
Design Load 4
Functional Class 6
Average Daily Traffic (ADT) 7

3.0 Deficiency Process for Local and County Structures 8
Parsing the Local and County Inventory 8
Single Inventory Grouping. 8
Design Load Parsing. 8
Functional Class Parsing 9
Deficiency Process 10

4.0 Database Items and Relative Weights 12

5.0 Summary of Results 14
Prioritized Deficiency List 15
Vertical Clearance 17
Geographical Distribution 18
Summary 21

6.0 Recommendations for Locally-Owned Bridge Structures 22
Minimal Load for Locally-Owned Bridge Structures 22
Vertical Clearance for Locally-Owned Bridge Structures 22
Additional Descriptive Fields for Subgrouping 23

7.0 Recommendations for State-Owned Bridge Structures 24
Extending the Forecast Time Planning Horizon 24
Deficiency Value Tie Breaking 24

8.0 Conclusions 29
Project Benefits 29
Future Research 30

9.0 References 31

Appendix A: ALDOT Bridge Replacement Program 32
Appendix B: Principles of Algorithm Development 33
Appendix C: Flow Chart of Deficiency Algorithm 35

List of Tables

Number		Page
2-1	Functional Classification and Associated Attributes	7
3-1	Functional Classes and Associated Subclasses	10
4-1	Bridge Database Items and Relative Weight for New Deficiency Algorithm	12
5-1	Deficiency Counts, Local and County Bridges (with Culverts)	14
5-2	Active Variable Count per Structure	14
5-3	1-100 Prioritized Structures (Using Functional Class or Group Discriminator)	16
5-4	Division Counts for Deficiency (1-100) by Functional Class	17
5-5	Vertical Clearance Summary	17
7-1	Tie Breaking Sequence	25
7-2	Prioritized State-Owned Structures (1-100)	26

List of Figures

Number		Page
2-1	Construction (span kind) and material (span type) for local and county structures	3
2-2	Design load	4
2-3	Operational rating verses design load	5
2-4	Functional class	6
2-5	Average daily traffic (ADT) and percent truck traffic	7
3-1	Deficiency process for local and county bridges	11
5-1	Deficiency scores (total, load, condition, width, and vertical) for 1-1000 structures	15
5-2	Deficiency scores (single group) for 1-1000 structures	15
5-3	1-250 local and country structures with deficiency scores	19
5-4	Vertical deficiency structures with BIN	20

Executive Summary

Facilitation of bridge Maintenance, Repair and Rehabilitation (MR&R) interventions necessitates the development and validation of a condition assessment metric that supports prioritization of bridge structures (that is, bridges and culverts) in a systematic, repeatable manner. Such a condition assessment metric must meet the objectives of transportation agency decision makers.

The deficiency metric developed in the reported study provides summary characteristic comparisons between bridges in the inventory database to state-wide performance standards called level of service (LOS) goals. The deficiency metric is aligned with ALDOT's bridge maintenance management policies to select, from a short list of "needy" bridges, the bridges most deficient and in need of replacement or rehabilitation.

The focus of this study was to extend the success of the research for locally-owned bridges and to extend the planning time horizon for state-owned bridges. The inherent nature of local and county structures prevents a direct application of the formulation described for the state solution. Consequently, a process to segregate structures based on capability and intended purpose was utilized. Each subgroup of bridges has a specific set of parameters that produces a more accurate assessment of the subgroup's current condition with respect to deficiency. These subgroups are consolidated to a global deficiency list to present a single prioritized reference for all local and county structures.

The duplication of index values of multiple structures is addressed by defining a set of stringent filtering rules. This ensured the prioritization of structures based on their attributes instead of random positioning that occurs when index values are the same for multiple structures. The filtering technique allows for the creation of a five-seven year plan (for the maintenance of 250 structures) by validating the positions of structures that otherwise would be banded due to identical total scores. This single list consolidates requirements throughout the state and at all levels of utility to ensure an unbiased selection process can be executed.

The goal of this project was to extend the "common sense" heuristics developed in ALDOT ***Project #930-661, Bridge Heath Monitoring Metrics*** to calculate bridge relative deficiency based on physical bridge characteristics represented in the bridge management system database. The algorithm's criteria and weight factors were adjusted by comparing the deficiency rankings against the judgment of experienced ALDOT engineers and bridge inspectors.

1.0 Introduction

Facilitation of bridge Maintenance, Repair and Rehabilitation (MR&R) interventions necessitates the development and validation of a condition assessment metric that supports prioritization of bridge structures (that is, bridges and culverts) in a systematic, repeatable manner. Such condition assessment metrics must meet the objectives of transportation agency decision makers. Appendix A summarizes The Alabama Department of Transportation's (ALDOT) Bridge Replacement Program as follows:

> *"The program specifies that a prioritized list of bridges to be replaced is produced by the Maintenance Bureau. Initial list is produced by ABIMS with bridges ranked by their deficiency score. Higher numbers represent bridges in worse shape; lower numbers represent bridges in better shape."*

Thus, as part of bridge management, ALDOT managers must decide how best to spend ALDOT's bridge replacement funds. In making these decisions, a deficiency algorithm is used to rank bridges that are the most deficient and in need of replacement. This algorithm was updated in 2008 for state-owned bridges in ***ALDOT Project #930-661, Bridge Heath Monitoring Metrics: Updating the Bridge Deficiency Algorithm***.

The state-owned bridge deficiency metric provides summary characteristic comparisons between bridges in the inventory database to state-wide performance standards called level of service (LOS) goals. The deficiency metric is aligned with ALDOT's bridge maintenance management policies to select, from a short list of "needy" bridges, the bridges most deficient and in need of replacement or rehabilitation.

ALDOT research project #930-661 focused on state-owned bridges and validated the prioritization over a three year planning horizon. The deficiency algorithm consists of four factors (load, width, vertical clearance, structural condition inspection rating). The deficiency algorithm (the factors and their coefficients), the associated decision analysis tool, and a series of scenarios that vary the prioritization (e.g., weights) of the four factors and comparisons to other states have been evaluated by the Maintenance Bureau, the County Transportation Bureau and division engineers. The implementation of ALDOT #930-661 identified two extensions needed be addressed to support the Alabama's Bridge Replacement Program:

1. <u>Extended Planning Time Horizon</u>: The algorithm reported by ALDOT #930-661 was validated to rank bridges in deficiency order for up to three years in the future. During ALDOT's implementation, ranking of the 250 most "needy" state structures was requested so that a five-seven year planning horizon could be evaluated.

2. Extension to Locally-owned Bridges: The algorithm reported by ALDOT #930-661 was validated for state-owned bridges, with general input concerning county and municipal bridges. During ALDOT's implementation of 930-661, the need to extension of the deficiency algorithm to locally-owned bridges has been identified as essential to allow ALDOT to fulfill its charge to assist municipal and county departments of transportation ensure that their bridges are safe and that state controlled funds are used efficiently to maintain these bridges.

Goal For This Project (ALDOT Project 930-742)

In response to the recognized needs for model extension, the goal of this project is to extend the "common sense" heuristic to calculate relative bridge deficiency based on physical bridge characteristics represented in the bridge management system database. Building on the success of ALDOT Project #930-661, which developed a new algorithm for deficiency and was used to rank state-owned bridge structures, this project expended a majority of its resources on extending the new deficiency metric to locally-owned bridge structures. This report is divided into sections that map the process used to extend the deficiency algorithm and associated heuristics.

Section 2 describes the differences between the state inventory and the local and county inventory. This section shows the broader range of values which are contained within the local and county inventory and the need to expand the current process used to evaluate state structures when considering local and county structures.

Section 3 describes the process used to develop the algorithm to account for multiple values of each parameter used to determine deficiency.

Section 4 describes the application of Section 3 with the new algorithm to create a local and county deficiency ranking.

Section 5 summarizes the results of Section 4 and presents the global maintenance priority list based on 2009 ALDOT data.

Section 6 presents recommendations to implement the deficiency heuristic for locally-owned bridge structures.

Section 7 presents recommendations to extend the planning time horizon to 5-7 years based on differentiated deficiency values for at least 250 bridges.

Section 8 presents conclusions and future research.

2.0 Comparison of State and Local Structure

Exploring the characteristics of a structures pool assists in defining the population. While these attributes may not be contained within the final algorithm, their descriptiveness assists in providing insight into the population's behavior.

Construction and Material Type

Figure 2-1 describes the different material and construction types used for local and county structures. Items 43A and 43B are the variable identifiers in the Alabama Bridge Inventory Management System (ABIMS) for these two components. While this information is not used directly in the construction of the algorithm, it is important to see the multiple combinations that exist in the local and county inventory and the areas of concentration that can be applied to benefit the greatest portion for future research.

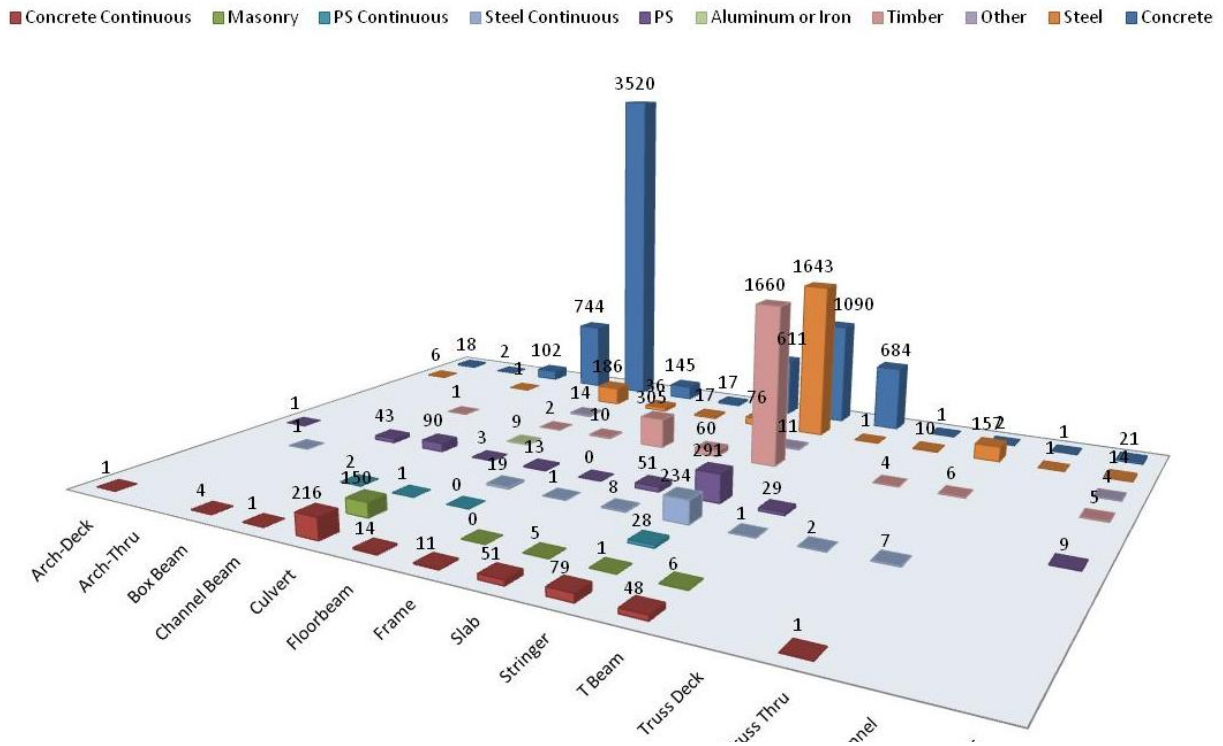


Figure2-1. Construction (span kind) and material (span type) for local and county structures.

Design Load

Design load is the specified load that the bridge was initially constructed to support. Figure 2-2 displays the different levels of design and the corresponding number of structures within the inventory. While the majority of state structures fall within a single H20/HS20 design (corresponding to interstate and highway usage), the local and country structures cover a wide range of designs loads.

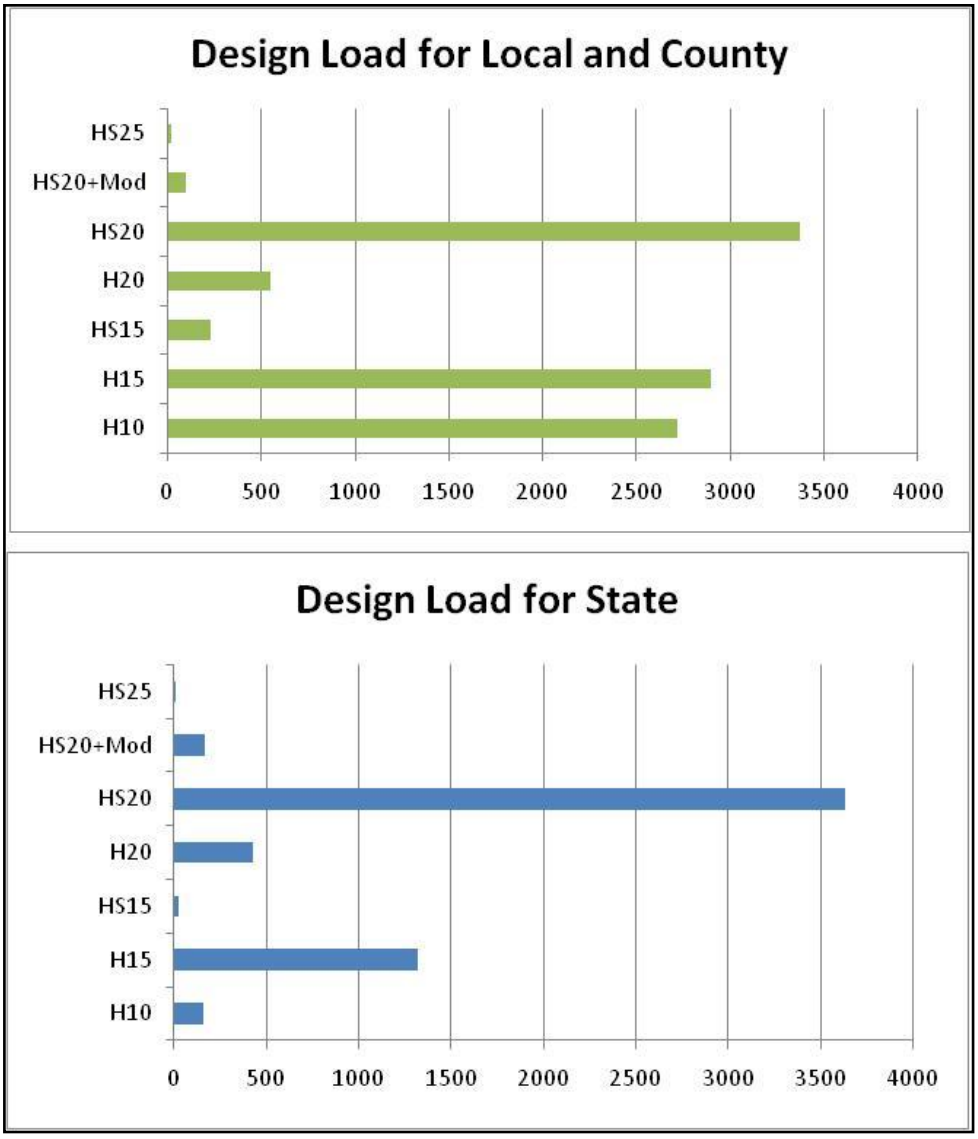


Figure 1-2. Design load[1].

[1] When making graphical comparisons of State to County and Local Structures throughout this document, State structures will be represented by ***blue*** and county and local structures will be represented by ***green.***

Figure 2-3 displays the operating rating (ABIMS item 64) compared to the design load (ABIMS item 31) categories. Note that for each design load the operational rating can vary greatly making a single point value for comparison difficult.

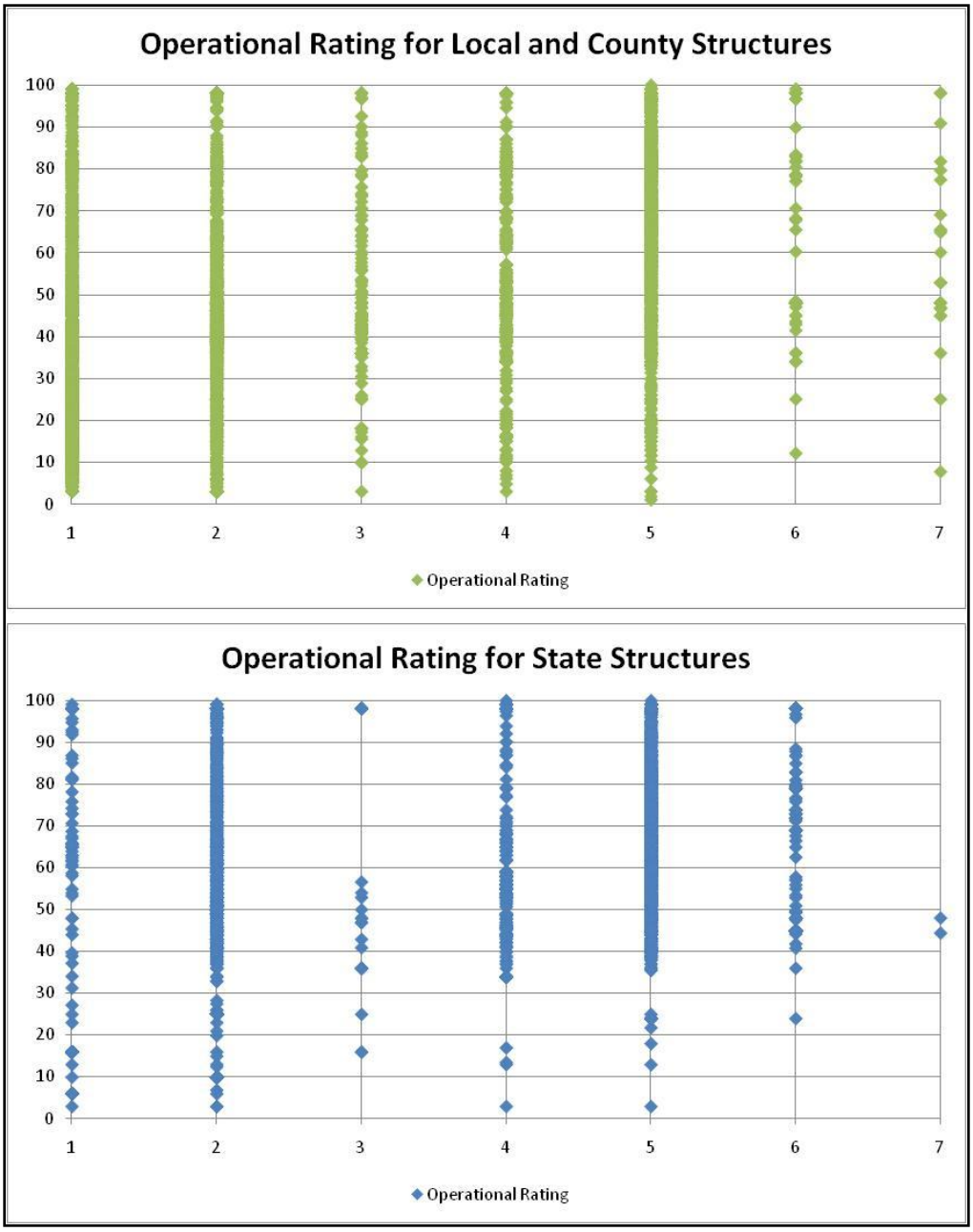


Figure 2-3. Operational rating verses design load.
(1: H10, 2: H15, 3: HS15, 4: H20, 5:HS20, 6: HS20+MOD, 7: HS25)

Functional Class

The functional class (item 26) describes the structures' purpose and utility. There are five functional classes and two sub classes (urban and rural) defined by ABIMS. Figure 2-4 displays the population count across the functional classes.

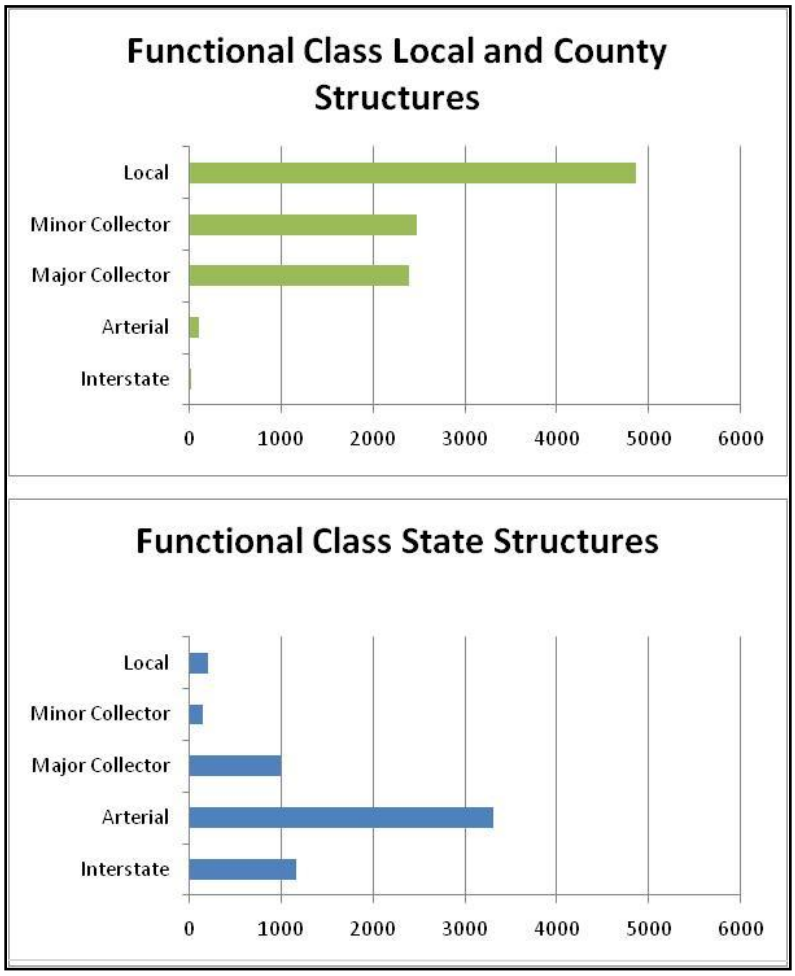


Figure 2-4. Functional class.

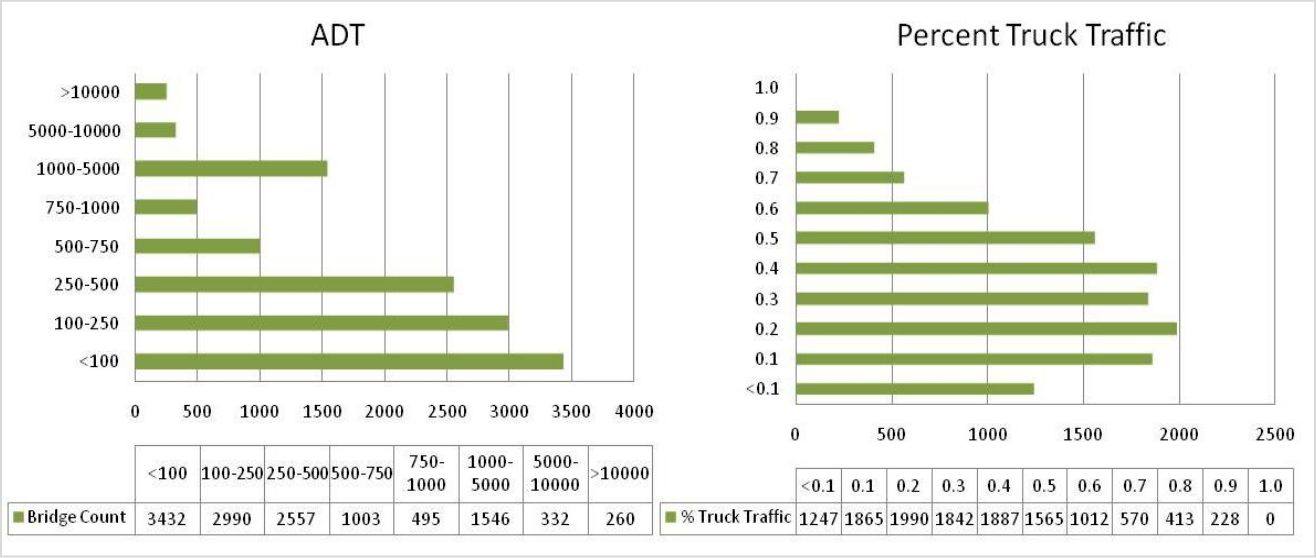
Table 2-1 defines the values for each parameter, as defined by ALDOT. Note that while many of the state-owned structures fall into a single category, the local and county bridge structures fall in several categories (with varying geometries and load capacities).

Table 2-1. Functional Classification and Associated Attributes

Functional Classification	Load Capacity, tons (Inventory Rating)	Width*, ft (n = number of lanes)	Vertical Clearance, ft
Interstate	36	12n + 2 + 2	16
Arterial	36	12n + 2 + 2	16
Major Collector	27	11n + 2 + 2	15
Minor Collector	18	10n + 1 + 1	15
Local	18	10n + 1 + 1	14

Average Daily Traffic (ADT)

Figure 2-5 displays the varying degrees of ADT for state-owned and local and county structures. The ADT variability within local bridges is greater than for state-owned structures. This is due in part to the fact that local bridges are located throughout the diverse transportation network. Local structures may be located in heavily concentrated areas (a city or near major arteries) or in remote rural areas which only support a few vehicles per day. This is evidenced by the high number of local structures that support less than 100 vehicles per day and the relatively low percentage of percent truck traffic present on the structures.



	<100	100-250	250-500	500-750	750-1000	1000-5000	5000-10000	>10000
Bridge Count	3432	2990	2557	1003	495	1546	332	260

	<0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
% Truck Traffic	1247	1865	1990	1842	1887	1565	1012	570	413	228	0

Figure 2-5. Average daily traffic (ADT) and percent truck traffic.

3.0 Deficiency Process for Local and County Structures

The deficiency of local structures must be evaluated using historic level of use data and future service goals. ALDOT 940-661 developed the deficiency algorithm for state-owned bridge structures with the expectation of a relatively consistent level of service for all state-owned structures; however, such an expectation for local structures does not hold. Thus, for local structures, the variability within the parameters used to determine deficiency is addressed so that each structure is evaluated against its designated purpose.

Parsing the Local and County Inventory

Three approaches to define each of the groupings for the different parameter values are evaluated. These methods are described individually, followed by a discussion of the chosen approach. The three evaluated methods are: (1) to allow the data to remain as a single inventory, (2) parse the inventory based on a structures' design load, and (3) parse the inventory based on its functional classification (purpose).

Single Inventory Grouping

This method is the simplest to institute and treats the structures using the same method as described for state deficiency analysis. A structure is graded on its capacity to meet a single set of threshold values. Initial results of this method are not surprising; local structures (reference Table 2-1) generate the highest deficiency scores since they are, by design, already below the initial threshold values. This is the dilemma of using a single set of values to compare multiple functional groups; a subgroup whose function was never intended to reach the described levels of support will continually score the highest amount of deficiency points and therefore will overshadow structures that are actually deficient for their designed purpose. This will hold true as threshold values are reduced since structures above the threshold will never receive points and local structures will be awarded maximum point values. The only discriminating factors are detour and ADT which raise a deficiency score (again, only if a threshold value is reached). Using a single inventory grouping is the least desirable method of the three techniques investigated for this study.

Design Load Parsing

Design load is the specified load that the bridge was initially constructed to support. The operational rating is defined as the capacity rating, or the maximum permissible load level to which the structure may be subjected for the vehicle type used in the rating. Figure 2-3 displays the various design load levels in the inventory and their associated operational rating. Figure 2-3

reveals that the discrepancy between the design load and the operational rating can vary greatly. Bridges may have their operational rating decreased due to decay or may have the rating increased from the application of additional support or shoring which has improved its capacity compared to the original design.

This discrepancy prevents an accurate comparison of design load to operational rating (which is a key component when determining load deficiency) since the route may have changed since its initial inception, which required an increase in the structure's capability. Therefore, parsing the data based on this parameter may create grouping (or cohorts) that do not define how the structure is presently employed. For example, if a structure has been reinforced to support increasing levels of traffic and loads since its original construction design, this information may not be captured accurately and when compared to other structures in this group may appear fully functional. The correlation[2] of the design load and the operational rating is 0.50; the remaining variability is largely due to the change of the load rating over time. It is this variability and the resultant potential masking of structures that reduces the effectiveness of parsing the inventory based on its design load.

Functional Class Parsing

Utilizing the functional class field (item 26), the purpose of the structure can be captured and a set of parameters which describes the appropriate weight and geometry can be applied to determine deficiency. This process of segregating the structures based on their purpose serves to capture the structure's current demands instead of its initial construction. University of Alabama researchers (BER #547-39) were able to quantify the parameters for each area (weight, vertical, and width goals for each of the functional classifications in Table 2-1) through expert solicitation, but these values were never implemented into a working model for calculating the deficiency of local and county structures. Utilizing the BER #547-39 work to separate the inventory into multiple cohorts based on their functional purpose presents a sound approach to ensure that structures are being compared to appropriate parameter values. While the correlation is stronger between Design Load and Operational Rating, the Functional Class and its accompanying values for geometry provide a better characterization of the whole structure. The correlation between the Functional Class and Design Load is 0.34 and the correlation between Functional Class and Operational Rating is 0.30.

The purpose of the deficiency rating is to prioritize the structures that are least capable of meeting a defined set of parameters. The rational for the initial parsing based on the functional class is to prioritize structures that are not capable of meeting the requirements of their present environment and to quickly identify those structures that may be candidates for functional reclassification because greater (or fewer) demands are being placed on it that its initial design did not consider. A structure that was initially designed for heavier loads and capacity may now be relegated to a lower functional class (a case where an interstate was constructed in close proximity) and therefore quickly exceeded its functional requirements. This structure can be

[2] A correlation is a single number that describes the degree of relationship between two variables. The values can vary between -1 to 1. The greater the absolute value the stronger the statistical relationship. Practically, the stronger the statistical relationship, the more one variable accurately predicts the value of the other.

ranked very low on its load rating and geometry with condition being the main influence for its deficiency score. It is for this reason that Functional Class is used to create independent cohorts for the initial deficiency calculations.

Deficiency Process

The first step in the process for calculating the deficiency rating of local and county structures is to separate the inventory into its respective functional classes. To match the functional classes in Table 2-1, the following classes are combined to generate five functional cohorts. Table 3-1 lists the functional classes and their associated subclasses.

Table 3-1. Functional Classes and Associated Subclasses

Functional Classification	Subclass	Secondary Subclass
Interstate	Rural or Urban	N/A
Arterial	Rural or Urban	Principal or Minor
Major Collector	Rural or Urban	N/A
Minor Collector	Rural or Urban	N/A
Local	Rural or Urban	N/A

Figure 3-1 represents the process for determining the overall deficiency score for the local and county inventory. The cohorts are separated based on functional classification (item 26) so that a uniform set of parameters representative of a particular group's purpose can be applied (Table 2-1). The deficiency will be calculated similarly to the state deficiency scores for each group. Once initial scoring is completed, the entire inventory will be sorted as a global list with Average Daily Traffic (ADT) used as a tie breaker to give priority to a structure which has the greatest amount of civil influence (that is, provides the greater good to the network).

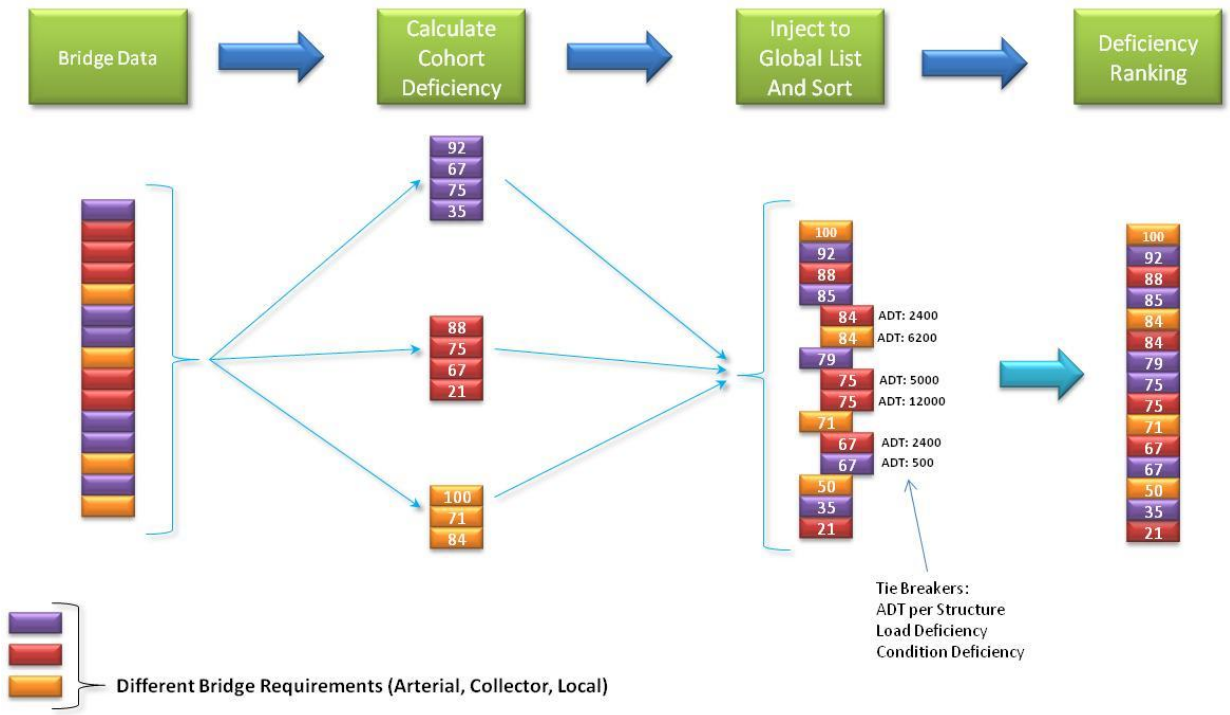


Figure3-1. Deficiency process for local and county bridges.

This process prevents the masking of issues within a cohort of structure types, thus deficiency values are calculated for each set of structure types. The result is a prioritized listing that is more representative of the actual health of the inventory.

4.0 Database Items and Relative Weights

The ALDOT Project #930-661 deficiency algorithm is described below. The algorithm was designed specifically for state-owned bridges and was developed based on the concept of bridge utility.

In the current study, the algorithm was applied to state-owned structures for an extended planning time horizon and to the local and county bridge structure inventory data. Table 4-1 displays the fields and corresponding weights used for the local and county calculations, which are consistent with the previous study.

Table4-1. Bridge Database Items and Relative Weight for New Deficiency Algorithm

Database Item	Relative Weight
Load Capacity Ratings	40
Condition Ratings	30
Bridge Width (curb-to-curb)	20
Vertical Clearance (on and under bridge)	10

Bridges with posted load or height restrictions prevent a certain percentage of truck traffic from using the bridge. Narrow bridges do not prevent use of a bridge, but nonetheless limit the utility of the bridge. For example, if a vehicle breaks down on a narrow bridge, the shoulder is typically not wide enough to allow the motorist to pull completely out of the traffic lane.

Bridges with poor condition ratings are nearing the end of their service lives due to deterioration and loss of structural integrity, and bridge replacement is typically a multi-year process. Therefore, bridges in poor condition should be assigned deficiency points so they can be replaced before their condition deteriorates to the point that they must be closed.

The load capacity ratings and condition ratings constitute the bulk of the possible deficiency points. While the other two deficiency categories (width and vertical clearance) involve a measurement of a single bridge feature, load ratings and condition ratings are based on many factors which are synthesized using engineering judgment to produce a numerical rating. These ratings, while less precise than measured bridge widths or vertical clearances, have significant meaning.

The relative weights were selected based on several factors including: a graphical summary of the distribution of bridge deficiencies, a bridge-by-bridge comparison of algorithm results, and a sensitivity study of multiple weighting scenarios. The specific algorithms for calculating

deficiency points and adjustment factors are described in detail in ALDOT #930-661. Interested readers are directed to that report for more details.

5. Summary of Results

A review of the results of applying the methods explained in section **Deficiency Process** with engineers from ALDOT's Maintenance and County Transportation Bureaus, provided support that the methods result in scores that are consistent with expert assessments. Table 5-1 summarizes the results based on the total deficiency score and the individual points (load, condition, width, and vertical).

Table 5-1. Deficiency Counts, Local and County Bridges (with Culverts)

	Total	Load	Condition	Width	Vertical
Active Inventory	9,943				
Deficient Structures	5,298	2,470	813	4,411	19
Maximum Points	N/A	1,085	139	31	15

The sum of individual counts is larger than the total because a single structure may contain more than one active deficiency (Table 5-2).

Table 1-2. Active Variable Count per Structure

	4 Variables	3 Variables	2 Variables	1 Variable
Variable Counts per Structure	4	395	2,004	3,292

Figure 5-1 displays the rank ordered results for the total and individual variable deficiency scores. The majority of the structures have maximum deficiency scores for the load factor (to include ADT and Detour factoring) which is supported by Table 5-1 (1,085 structures were identified with a maximum load deficiency). Points of interest in the graph are the relationship between load and condition; a decrease in load rating was usually accompanied with an increase in the condition deficiency. This occurs because the decay of a structure is measured every two years but the load rating remains static until the condition rating reaches a level where it is posted (reducing the operational rating). Once this occurs, the load remains deficient (below its designed level of service) but the condition may improve since it is fully capable of supporting the new requirement.

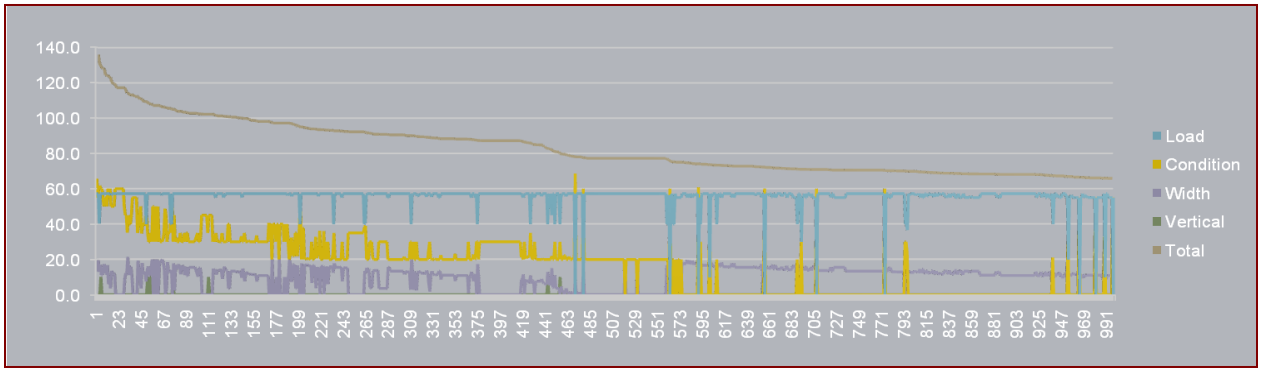


Figure 5-1. Deficiency scores (total, load, condition, width, and vertical) for 1-1000 structures.

The difference between Figures 5-1 and 5-2 is that Figure 5-2 represents the banded result. As described in ***Single Inventory Grouping***, the hypothesis is validated that bridges with small load capacities propagated to the front of the list because the parameter thresholds were far beyond their actual designed purpose. This is evident with the maximum score computed using the two approaches, where the first priority structure with no distinction among groups approached 150 deficiency points compared to the functional class grouping method which reached 136 points.

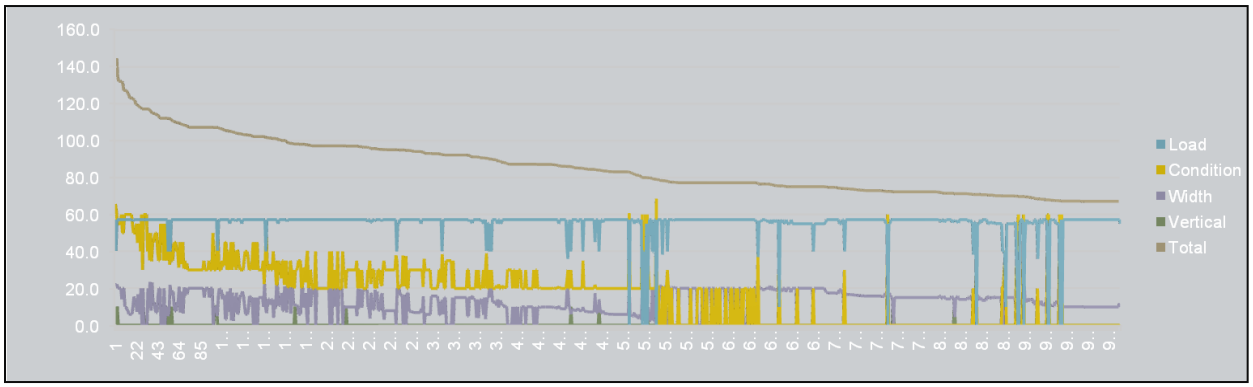


Figure 5-2. Deficiency scores (single group) for 1-1000 structures.

Prioritized Deficiency List

Table 5-3 presents the prioritized list of the highest deficiency-valued locally-owned structures. Note that the majority (66%) are part of the functional class “rural local” or “urban local.”

Table 5-3. 1-100 Prioritized Structures (Using Functional Class or Group Discriminator)

Bin	Owner	Functional_Class	Load_Defic	Cond_Defic	Width_Defic	Vert_Clear_Defic	Total_Defic	Rank
2747	County	Rural Major Collector	57.2	65.7	13.1	0.0	136.0	1
5989	County	Rural Minor Collector	57.2	55.0	19.6	0.0	131.8	1
3164	County	Rural Local	57.2	60.0	12.9	0.0	130.1	2
90	City	Urban Local	40.3	61.7	17.0	10.1	129.1	3
10893	County	Rural Local	57.2	60.0	11.1	0.0	128.3	4
3876	County	Rural Minor Collector	57.2	60.0	11.1	0.0	128.3	5
5743	County	Rural Minor Collector	57.2	55.0	15.6	0.0	127.8	6
7826	City	Rural Local	57.2	50.0	17.3	0.0	124.5	7
3067	County	Rural Major Collector	57.2	55.0	12.0	0.0	124.2	2
4948	County	Rural Major Collector	57.2	55.0	12.0	0.0	124.2	3
8938	City	Rural Local	57.2	50.0	16.7	0.0	123.9	8
11495	County	Rural Local	57.2	60.0	6.0	0.0	123.2	9
5022	County	Rural Local	57.2	55.0	10.9	0.0	123.1	10
16	County	Rural Local	57.2	60.0	3.6	0.0	120.8	11
3658	County	Rural Minor Collector	56.4	50.0	13.6	0.0	120.0	12
7090	County	Rural Local	57.2	50.0	12.2	0.0	119.4	14
4743	County	Rural Local	57.2	50.0	12.2	0.0	119.4	13
3525	County	Rural Local	57.2	50.0	11.6	0.0	118.8	15
1494	County	Rural Local	57.2	60.0	0.0	0.0	117.2	17
8615	County	Rural Major Collector	57.2	60.0	0.0	0.0	117.2	4
8616	County	Rural Local	57.2	60.0	0.0	0.0	117.2	19
3812	County	Rural Minor Collector	57.2	60.0	0.0	0.0	117.2	23
8614	County	Rural Local	57.2	60.0	0.0	0.0	117.2	18
18	County	Rural Local	57.2	60.0	0.0	0.0	117.2	16
2869	County	Rural Minor Collector	57.2	60.0	0.0	0.0	117.2	22
12128	County	Rural Local	57.2	60.0	0.0	0.0	117.2	20
14086	County	Rural Local	57.2	60.0	0.0	0.0	117.2	21
954	County	Rural Local	57.2	50.0	8.9	0.0	116.1	24
6384	County	Rural Local	57.2	45.0	12.2	0.0	114.4	25
7145	County	Rural Local	57.2	45.0	12.2	0.0	114.4	26
7524	City	Urban Local	57.2	35.2	21.4	0.0	113.8	27
9012	County	Rural Local	57.2	45.0	11.1	0.0	113.3	28
16754	County	Rural Minor Collector	57.2	40.0	15.9	0.0	113.1	30
825	City	Urban Local	57.2	40.0	15.9	0.0	113.1	31
3176	County	Rural Local	57.2	45.0	10.9	0.0	113.1	29
11321	County	Rural Local	57.2	55.0	0.8	0.0	113.0	32
3107	County	Rural Local	57.2	55.0	0.0	0.0	112.2	34
10891	County	Rural Local	57.2	55.0	0.0	0.0	112.2	35
12867	County	Rural Minor Collector	57.2	55.0	0.0	0.0	112.2	36
562	County	Rural Local	57.2	55.0	0.0	0.0	112.2	33
12473	County	Rural Local	57.2	35.0	19.3	0.0	111.5	37
3673	County	Rural Minor Collector	57.2	40.0	13.8	0.0	111.0	38
11597	City	Urban Local	57.2	42.6	11.1	0.0	111.0	39
321	County	Rural Local	57.2	50.0	3.6	0.0	110.8	40
315	City	Urban Minor Collector	57.2	34.6	18.0	0.0	109.8	41
6928	County	Rural Local	57.2	40.0	12.2	0.0	109.4	42
17160	County	Rural Local	57.2	40.0	12.2	0.0	109.4	43
1262	County	Rural Local	57.2	39.1	13.0	0.0	109.3	44
4074	County	Rural Major Collector	57.2	44.7	7.4	0.0	109.3	5
440	County	Rural Local	40.0	45.0	13.8	10.0	108.8	45
1164	County	Rural Local	57.2	35.0	16.0	0.0	108.2	46
3177	County	Rural Local	57.2	30.0	10.9	10.0	108.1	47
4048	County	Rural Local	57.2	30.0	10.9	10.0	108.1	48
13964	City	Urban Local	57.2	35.0	15.6	0.0	107.8	49
3122	County	Rural Minor Collector	57.2	30.0	20.0	0.0	107.2	54
5700	County	Rural Local	57.2	50.0	0.0	0.0	107.2	51
3548	County	Rural Local	57.2	50.0	0.0	0.0	107.2	50
6042	County	Rural Local	57.2	30.0	20.0	0.0	107.2	52
6850	County	Rural Local	57.2	50.0	0.0	0.0	107.2	53
9162	County	Rural Minor Collector	57.2	30.0	20.0	0.0	107.2	55
1434	County	Rural Major Collector	57.2	49.9	0.0	0.0	107.1	6
2289	City	Urban Local	57.2	32.8	17.0	0.0	107.0	56
17024	County	Rural Local	57.2	30.0	19.2	0.0	106.4	58
17022	County	Rural Local	57.2	30.0	19.2	0.0	106.4	57
17742	County	Rural Local	56.5	30.0	19.9	0.0	106.4	59
9693	County	Rural Local	57.2	31.3	17.7	0.0	106.2	60
949	County	Rural Local	57.2	35.0	13.8	0.0	106.0	61
11173	City	Urban Major Collector	57.2	48.8	0.0	0.0	106.0	7
849	County	Rural Local	57.2	45.0	3.6	0.0	105.8	62
17029	County	Rural Local	57.2	30.0	18.4	0.0	105.6	63
6625	County	Rural Minor Collector	57.2	35.0	13.3	0.0	105.5	64
12265	County	Rural Minor Collector	57.2	35.0	13.3	0.0	105.5	65
1536	County	Rural Local	57.2	35.0	12.9	0.0	105.1	66
91	City	Urban Local	40.4	50.7	13.9	0.0	105.1	67
2470	County	Rural Local	40.0	55.0	0.0	10.0	105.0	68
1873	County	Rural Local	57.2	30.0	17.8	0.0	105.0	69
13469	County	Rural Local	57.2	45.0	2.4	0.0	104.6	70
2248	County	Rural Minor Collector	57.2	30.0	17.0	0.0	104.2	71
4470	County	Rural Local	57.2	32.3	14.4	0.0	103.9	72
10911	County	Rural Local	57.2	30.0	16.7	0.0	103.9	73
5024	County	Rural Minor Collector	57.2	30.0	16.7	0.0	103.9	75
2753	County	Rural Minor Collector	57.2	30.0	16.7	0.0	103.9	74
11720	County	Rural Minor Collector	57.2	35.0	11.6	0.0	103.8	76
8	County	Rural Local	57.2	30.4	15.8	0.0	103.4	77
5197	County	Rural Local	57.2	30.0	16.2	0.0	103.4	78
2708	County	Rural Minor Collector	57.2	30.0	16.2	0.0	103.4	79
571	County	Rural Local	57.2	35.0	11.1	0.0	103.3	80
1869	County	Rural Minor Collector	57.2	30.0	15.9	0.0	103.1	81
13846	County	Rural Minor Collector	57.2	35.0	10.9	0.0	103.1	82
6074	County	Rural Major Collector	57.2	35.0	10.6	0.0	102.8	8
1408	City	Urban Local	57.2	30.0	15.6	0.0	102.8	89
7061	City	Rural Minor Collector	57.2	30.0	15.6	0.0	102.8	86
5684	County	Rural Local	57.2	30.0	15.6	0.0	102.8	84
541	County	Rural Minor Collector	57.2	30.0	15.6	0.0	102.8	87
11168	County	Rural Local	57.2	30.0	15.6	0.0	102.8	85
1204	County	Rural Minor Collector	57.2	30.0	15.6	0.0	102.8	88
1159	County	Rural Local	57.2	30.0	15.6	0.0	102.8	83
5801	County	Rural Local	57.2	31.5	14.0	0.0	102.8	90
1213	County	Rural Minor Collector	57.2	33.1	12.3	0.0	102.6	91
10752	County	Rural Local	57.2	35.0	10.2	0.0	102.4	93

The remaining 33% of structures are collectors (major and minor). No arterial structures are included in the prioritized list, as evident in Table 5-4. The distribution of collector and local structures indicates that there is no banding occurring as with the single group approach. An explanation for the lack of arterial structures is their requirement to feed more congested or heavily used structures (highways and interstates), which necessitates greater conservation and these structures may have already received improvements to meet those guidelines and facilitate commercial traffic.

Table5-4. Division Counts for Deficiency (1-100) by Functional Class

Division	1	2	3	4	5	6	7	8	9
Arterial	0	0	0	0	0	0	0	0	0
Collector	22	9	3	8	16	2	5	9	14
Local	25	17	26	28	24	6	3	24	9

Vertical Clearance

Vertical clearance is a geometric constraint because it limits the type of vehicles that may utilize these structures. A vertical constraint prevents many larger commercial vehicles from utilizing the structures and requires deviation to an alternate path that can accommodate the traffic. The purpose of this section is to explain the low weighting of the vertical deficiency and the impact of varying the service values (height constraints) for determining deficient structures.

The number of local and county structures with a vertical clearance deficiency is low, and therefore this factor plays a limited role in determining the deficiency for these structures. Most structures are either built without a vertical constraint (majority) or the clearance meets or exceeds the current requirements. This will be discussed more in the recommendations section for locally owned bridges (Section 6) but for demonstration purposes the constraint of 13.5 feet (correlated to the state height limit for trucks) is compared to a vertical measurement of 16 feet (the same vertical clearance used for interstate and highway) for all structures. Table 5-5 summarizes the results from comparing the two model runs. Note the small population even when the maximum threshold value (16 feet) is used against all structures within the inventory.

Using a small weighting value for the vertical deficiency (10%, Table 4-1) allows vertical clearance to be used as a deficiency enhancement. If a structure has already gained a substantial score in the other areas then the vertical weight would slightly increase this score, similar to the detour and ADT factoring. At the same time it prevents vertical deficiency from becoming a primary driver for determining priority and overshadowing a structure that may have more safety related issues.

Table 5-5. Vertical Clearance Summary

Constraint	Total	Overhead	Under	Both	Not Deficient
13.5’	13	8	5	0	9,930
16’	27	20	7	0	9,916
Structures between 13.5’ and 16’	14	N/A	N/A	N/A	N/A

Geographical Distribution

The geographical distribution of the deficient structures was of concern since an issue of funding may arise if an area has a high concentration of deficient structures compared to other surrounding counties or divisions. Figure 5-3 is a geo-referenced map of the 250 locally-owned structures with the highest deficiency values. Note that the distribution is not concentrated to any specific portion of the state and follows the main network flows throughout the region. The only area where the concentration appears above average was Conecuh County with seven Collectors and four Local structures within the first 250 deficiency structures.

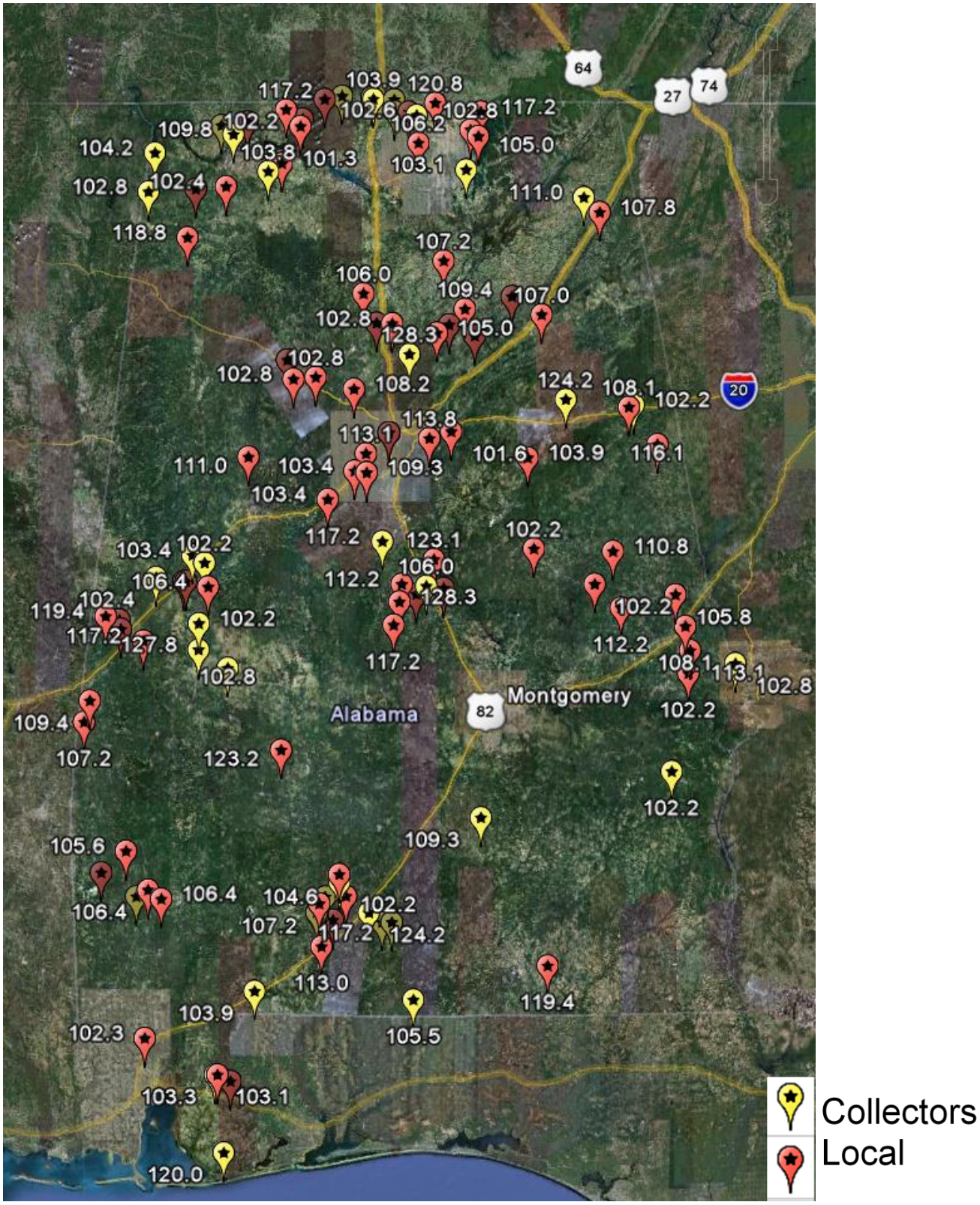


Figure 5-3. 1-250 local and country structures with deficiency scores.

The vertical deficiency for those structures which are below the 13.5 feet threshold for either over or under clearance (**Vertical Clearance**) is displayed in Figure 5-4. There appears to be a single concentration of 13 structures northeast of Birmingham between Interstates 65 and 59 which do not meet this minimal level of service. All of these structures are local bridges with more than a third being an under-clearance deficiency.

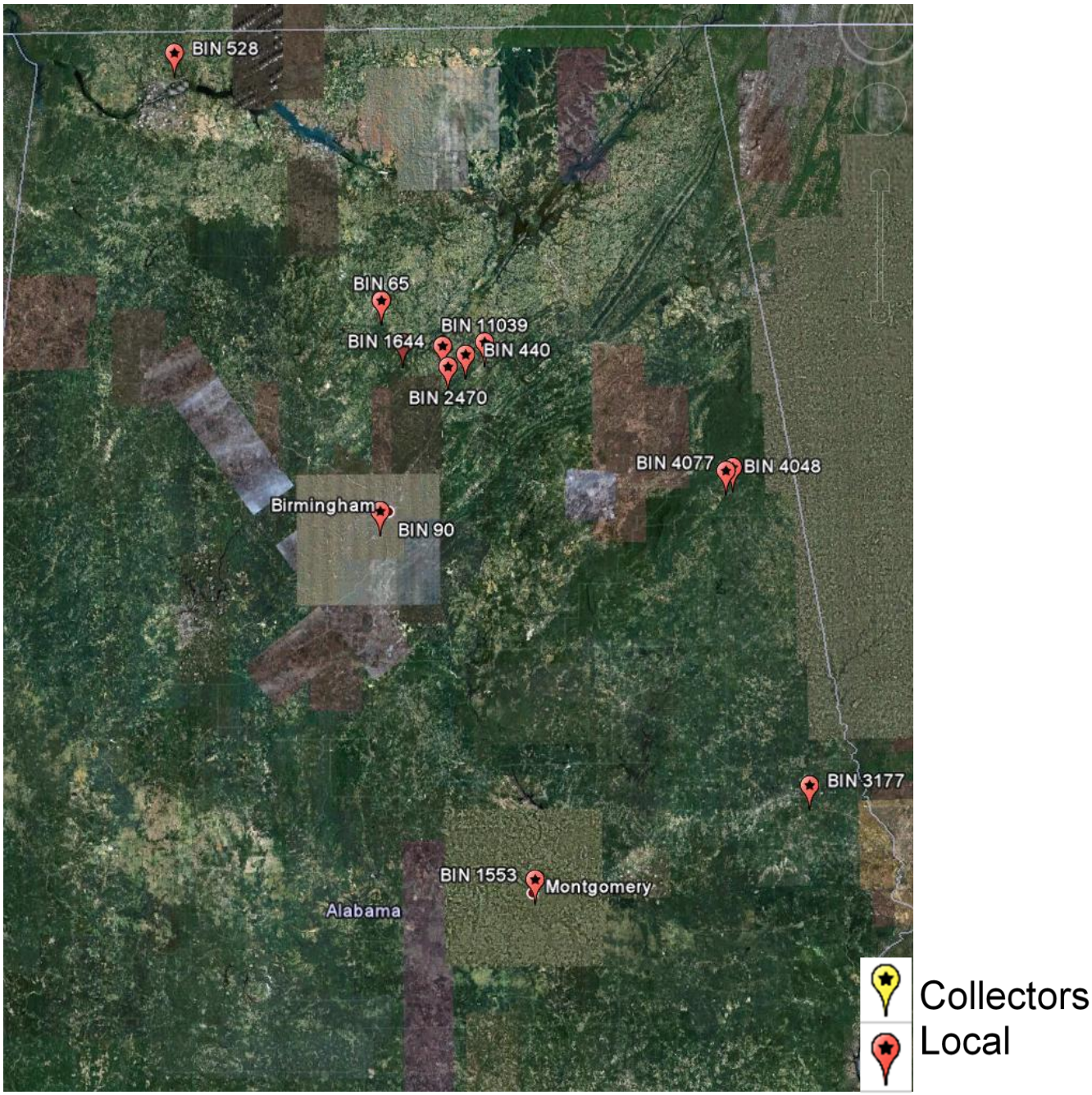


Figure5-4. Vertical deficiency structures with BIN.

Summary

The solution presented in this report is able to generate a transparent, standard, repeatable process for calculating a prioritized listing of local and county deficient structures. The deficiency list was constructed against a set of thresholds which were altered to represent different scenarios (e.g. vertical clearance, load capacity) and vetted against the inventory for consistency. In all examples the prioritized listing was reliable with respect to the thresholds and their rank position values. The use of a tie breaker based on ADT prevents identical scores from alternating within subsequent runs by forcing structures with a larger usage rate to rank higher on the list.

6.0 Recommendations for Locally-Owned Bridge Structures

The results from this work were presented to ALDOT Bridge Maintenance managers in December 2009. The approach was accepted as a feasible solution to prioritizing the local and county inventories with the addition of a few points to reflect policy changes and to assist with further granularity and tie breakers within competing structures.

Minimal Load for Locally-Owned Bridge Structures

ALDOT project #930-649, (PI, Dr. J. Richardson, The University of Alabama) is currently investigating the minimal requirement for a structure to safely support a school bus. Currently the minimal requirement is 12.5 tons. Research is now supporting that this limit should be increased to 15 tons to accommodate the increase in bus weights due to newer designs for safety and larger capacity vehicles.

The effect on the rating scores will be reflected by an increase in deficiency points for structures below the threshold, while structure above this threshold will not benefit from additional points. As a result, structures below 15 tons could overtake previous structures (which may be deficient on the other variables). The net effect on the entire inventory could be an increase in priority of these structures within the global listing. While this is acceptable since this involves a safety issue, this policy change could produce over-inflated deficiency scores for structures which are not on a bus route. Therefore, one recommendation to lessen this effect is to add an additional variable for tracking if a structure is located along a bus route and therefore subject to this higher rating.

An added benefit of this “school bus route” variable could be the further granulation of the solution set. Using it as either an independent variable or as a factor (similar to the ADT and detour factoring) another group of structures could be culled out of the inventory to meet this safety guideline while preventing the deficiency ratings of similar structures off the route from becoming inflated. This would quickly sort the hierarchy since school bus routes would be compared to a higher load capacity and therefore its deficiency would be higher due to the capacity gap.

Vertical Clearance for Locally-Owned Bridge Structures

Table 5-5, Vertical Clearance Summary provides the results of structures that are height restricted in the Alabama inventory. At a threshold of 13.5 foot clearance, a total of 13 structures are deficient. At 16 foot clearance an additional 14 structures are deficient. After discussion with

Maintenance Bureau and County Transportation Bureau engineers, the recommendation is to use a 13.5 foot clearance (legal limit) for all structures regardless of their functional designation. An alternative discussed was the use of a graduated vertical clearance to distinguish the three different functional classes; however, this was rejected as being subjective.

Additional Descriptive Fields for Subgrouping

Tighter threshold values could be applied to further refine the division of the inventory into a greater number of homogenous cohort groups. Based on the current fields within the inventory the functional classes could be further divided into rural and urban fields, and collectors could be further divided into principle, major, and minor sets. This would only be necessary if another set of identifiable thresholds could be extracted to allow for a better "fit" of the data to the values. The method of creating a global list would remain unchanged but would simply propagate more subgroups.

Another alternative would be to separate structures based on their purposes above their functional class to delineate between ramps and bridges. This has not been performed in any previous work. Thus the threshold values to apply (if there is a physical difference in the requirement) and the resulting impact on prioritization is not known.

7.0 Recommendations for State-Owned Bridge Structures

To meet current federal guidelines states must now produce a five year plan (extendable to seven years) for deficiency priorities. The need to produce this plan over this length of time requires a set of sorting rules which will generate a reliable and repeatable process which can withstand scrutiny during the funding process.

Extending the Forecast Time Planning Horizon

Approximately 30-50 structures annually may be funded for replacement throughout the state at the local and county levels. To create a five year plan, approximately 250 structures are required to be identified in a prioritized listing every year. Applying the sequencing (sorting rules) detailed in Table 7-1 as defined by the Maintenance Bureau and County Transportation Bureau engineers, any structures with the same deficiency value will remain in the same ranked order position. This enables a banded set of structures to still maintain a position based on its requirements (reference **Deficiency Value Tie Breaking**). This is an important step in distinguishing structures as funding becomes available and the cutoff point is between two structures with the same total deficiency score. Without the ability to consistently order lengthy runs of structures that are banded based on total deficiency, it would be difficult to justify which project to support.

Deficiency Value Tie Breaking

The current method to break ties is by ADT alone, which is performed after the global set is sorted based on deficiency score. This method, though effective, can be made more robust through a series of sorts which eliminate the possibility of two structures with the same deficiency score and a single tie breaking value. The focus is directed more on deficiency than on the current usage of the structure. Table 7-1 lists the sorting sequence for the deficiency ranking to ensure no ties exist. It is a repeatable process to determine that rank position remains consistent.

Table 7-1. Tie Breaking Sequence

Process (Sort Pass)	Field
Initial Ranking	Deficiency Score
1	Condition Rating
2	Load Capacity
3	Width (Safety)
4	Vertical (Commerce)
5	AADT (Usage)

Table 7-2 displays the ordered set of 250 structures to be used for a five-seven year planning time horizon. The use of the tie breaker rules provides the ordering when identical values are computed. Within this set of 250 structures, no arterial structures are present. Rather the 250 structures are local and collector structures.

Table 7-2. Prioritized State-Owned Structures (1-100)

Bin	Owner	Functional_Class	Load_Defic	Cond_Defic	Width_Defic	Vert_Clear_Defic	Total_Defic	Rank
2747	County	Rural Major Collector	57.2	65.7	13.1	0.0	136.0	1
5989	County	Rural Minor Collector	57.2	55.0	19.6	0.0	131.8	1
3164	County	Rural Local	57.2	60.0	12.9	0.0	130.1	2
90	City	Urban Local	40.3	61.7	17.0	10.1	129.1	3
10893	County	Rural Local	57.2	60.0	11.1	0.0	128.3	4
3876	County	Rural Minor Collector	57.2	60.0	11.1	0.0	128.3	5
5743	County	Rural Minor Collector	57.2	55.0	15.6	0.0	127.8	6
7826	City	Rural Local	57.2	50.0	17.3	0.0	124.5	7
3067	County	Rural Major Collector	57.2	55.0	12.0	0.0	124.2	2
4948	County	Rural Major Collector	57.2	55.0	12.0	0.0	124.2	3
8938	City	Rural Local	57.2	50.0	16.7	0.0	123.9	8
11495	County	Rural Local	57.2	60.0	6.0	0.0	123.2	9
5022	County	Rural Local	57.2	55.0	10.9	0.0	123.1	10
16	County	Rural Local	57.2	60.0	3.6	0.0	120.8	11
3658	County	Rural Minor Collector	56.4	50.0	13.6	0.0	120.0	12
7090	County	Rural Local	57.2	50.0	12.2	0.0	119.4	14
4743	County	Rural Local	57.2	50.0	12.2	0.0	119.4	13
3525	County	Rural Local	57.2	50.0	11.6	0.0	118.8	15
1494	County	Rural Local	57.2	60.0	0.0	0.0	117.2	17
8615	County	Rural Major Collector	57.2	60.0	0.0	0.0	117.2	4
8616	County	Rural Local	57.2	60.0	0.0	0.0	117.2	19
3812	County	Rural Minor Collector	57.2	60.0	0.0	0.0	117.2	23
8614	County	Rural Local	57.2	60.0	0.0	0.0	117.2	18
18	County	Rural Local	57.2	60.0	0.0	0.0	117.2	16
2869	County	Rural Minor Collector	57.2	60.0	0.0	0.0	117.2	22
12128	County	Rural Local	57.2	60.0	0.0	0.0	117.2	20
14086	County	Rural Local	57.2	60.0	0.0	0.0	117.2	21
954	County	Rural Local	57.2	50.0	8.9	0.0	116.1	24
6384	County	Rural Local	57.2	45.0	12.2	0.0	114.4	25
7145	County	Rural Local	57.2	45.0	12.2	0.0	114.4	26
7524	City	Urban Local	57.2	35.2	21.4	0.0	113.8	27
9012	County	Rural Local	57.2	45.0	11.1	0.0	113.3	28
16754	County	Rural Minor Collector	57.2	40.0	15.9	0.0	113.1	30
825	City	Urban Local	57.2	40.0	15.9	0.0	113.1	31
3176	County	Rural Local	57.2	45.0	10.9	0.0	113.1	29
11321	County	Rural Local	57.2	55.0	0.8	0.0	113.0	32
3107	County	Rural Local	57.2	55.0	0.0	0.0	112.2	34
10891	County	Rural Local	57.2	55.0	0.0	0.0	112.2	35
12867	County	Rural Minor Collector	57.2	55.0	0.0	0.0	112.2	36
562	County	Rural Local	57.2	55.0	0.0	0.0	112.2	33
12473	County	Rural Local	57.2	35.0	19.3	0.0	111.5	37
3673	County	Rural Minor Collector	57.2	40.0	13.8	0.0	111.0	38
11597	City	Urban Local	57.2	42.6	11.1	0.0	111.0	39
321	County	Rural Local	57.2	50.0	3.6	0.0	110.8	40
315	City	Urban Minor Collector	57.2	34.6	18.0	0.0	109.8	41
6928	County	Rural Local	57.2	40.0	12.2	0.0	109.4	42
17160	County	Rural Local	57.2	40.0	12.2	0.0	109.4	43
1262	County	Rural Local	57.2	39.1	13.0	0.0	109.3	44
4074	County	Rural Major Collector	57.2	44.7	7.4	0.0	109.3	5
440	County	Rural Local	40.0	45.0	13.8	10.0	108.8	45
1164	County	Rural Local	57.2	35.0	16.0	0.0	108.2	46
3177	County	Rural Local	57.2	30.0	10.9	10.0	108.1	47
4048	County	Rural Local	57.2	30.0	10.9	10.0	108.1	48
13964	City	Urban Local	57.2	35.0	15.6	0.0	107.8	49
3122	County	Rural Minor Collector	57.2	30.0	20.0	0.0	107.2	54
5700	County	Rural Local	57.2	50.0	0.0	0.0	107.2	51
3548	County	Rural Local	57.2	50.0	0.0	0.0	107.2	50
6042	County	Rural Local	57.2	30.0	20.0	0.0	107.2	52
6850	County	Rural Local	57.2	50.0	0.0	0.0	107.2	53
9162	County	Rural Minor Collector	57.2	30.0	20.0	0.0	107.2	55
1434	County	Rural Major Collector	57.2	49.9	0.0	0.0	107.1	6
2289	City	Urban Local	57.2	32.8	17.0	0.0	107.0	56
17024	County	Rural Local	57.2	30.0	19.2	0.0	106.4	58
17022	County	Rural Local	57.2	30.0	19.2	0.0	106.4	57
17742	County	Rural Local	56.5	30.0	19.9	0.0	106.4	59
9693	County	Rural Local	57.2	31.3	17.7	0.0	106.2	60
949	County	Rural Local	57.2	35.0	13.8	0.0	106.0	61
11173	City	Urban Major Collector	57.2	48.8	0.0	0.0	106.0	7
849	County	Rural Local	57.2	45.0	3.6	0.0	105.8	62
17029	County	Rural Local	57.2	30.0	18.4	0.0	105.6	63
6625	County	Rural Minor Collector	57.2	35.0	13.3	0.0	105.5	64
12265	County	Rural Minor Collector	57.2	35.0	13.3	0.0	105.5	65
1536	County	Rural Local	57.2	35.0	12.9	0.0	105.1	66
91	City	Urban Local	40.4	50.7	13.9	0.0	105.1	67
2470	County	Rural Local	40.0	55.0	0.0	10.0	105.0	68
1873	County	Rural Local	57.2	30.0	17.8	0.0	105.0	69
13469	County	Rural Local	57.2	45.0	2.4	0.0	104.6	70
2248	County	Rural Minor Collector	57.2	30.0	17.0	0.0	104.2	71
4470	County	Rural Local	57.2	32.3	14.4	0.0	103.9	72
10911	County	Rural Local	57.2	30.0	16.7	0.0	103.9	73
5024	County	Rural Minor Collector	57.2	30.0	16.7	0.0	103.9	75
2753	County	Rural Minor Collector	57.2	30.0	16.7	0.0	103.9	74
11720	County	Rural Minor Collector	57.2	35.0	11.6	0.0	103.8	76
8	County	Rural Local	57.2	30.4	15.8	0.0	103.4	77
5197	County	Rural Local	57.2	30.0	16.2	0.0	103.4	78
2708	County	Rural Minor Collector	57.2	30.0	16.2	0.0	103.4	79
571	County	Rural Local	57.2	35.0	11.1	0.0	103.3	80
1869	County	Rural Minor Collector	57.2	30.0	15.9	0.0	103.1	81
13846	County	Rural Minor Collector	57.2	35.0	10.9	0.0	103.1	82
6074	County	Rural Major Collector	57.2	35.0	10.6	0.0	102.8	8
1408	City	Urban Local	57.2	30.0	15.6	0.0	102.8	89
7061	City	Rural Minor Collector	57.2	30.0	15.6	0.0	102.8	86
5684	County	Rural Local	57.2	30.0	15.6	0.0	102.8	84
541	County	Rural Minor Collector	57.2	30.0	15.6	0.0	102.8	87
11168	County	Rural Local	57.2	30.0	15.6	0.0	102.8	85
1204	County	Rural Minor Collector	57.2	30.0	15.6	0.0	102.8	88
1159	County	Rural Local	57.2	30.0	15.6	0.0	102.8	83
5801	County	Rural Local	57.2	31.5	14.0	0.0	102.8	90
1213	County	Rural Minor Collector	57.2	33.1	12.3	0.0	102.6	91
10752	County	Rural Local	57.2	35.0	10.2	0.0	102.4	93

Table 7-2. Prioritized State-Owned Structures (101-200) (continued)

4038	County	Rural Local	57.2	30.0	15.2	0.0	102.4	92	1316	City	Urban Local	40.0	55.0	0.0	0.0	95.0	183
6222	County	Rural Minor Collector	57.2	30.0	15.2	0.0	102.4	94	3811	City	Rural Local	57.2	20.0	17.8	0.0	95.0	184
3441	City	Rural Local	57.2	32.6	12.5	0.0	102.3	95	2401	County	Rural Local	57.2	37.8	0.0	0.0	95.0	185
8788	County	Rural Local	57.2	45.1	0.0	0.0	102.3	96	1215	County	Rural Major Collector	57.2	37.5	0.0	0.0	94.7	19
1599	County	Rural Local	57.2	45.0	0.0	0.0	102.2	100	3337	County	Rural Local	57.2	20.0	17.3	0.0	94.5	186
138	City	Rural Local	57.2	45.0	0.0	0.0	102.2	97	5676	County	Rural Local	57.2	20.6	16.7	0.0	94.5	187
5970	County	Rural Minor Collector	57.2	45.0	0.0	0.0	102.2	104	1263	County	Rural Local	57.2	20.0	17.2	0.0	94.4	188
1632	County	Rural Local	57.2	45.0	0.0	0.0	102.2	101	3655	County	Rural Minor Collector	57.2	20.4	16.6	0.0	94.2	189
3381	County	Rural Minor Collector	57.2	45.0	0.0	0.0	102.2	102	437	County	Rural Minor Collector	57.2	20.8	16.2	0.0	94.2	190
4077	County	Rural Major Collector	57.2	35.0	0.0	10.0	102.2	9	3656	County	Rural Minor Collector	57.2	20.4	16.2	0.0	93.9	191
1535	County	Rural Local	57.2	45.0	0.0	0.0	102.2	99	4041	County	Rural Local	57.2	20.0	16.7	0.0	93.9	193
5731	County	Rural Minor Collector	57.2	45.0	0.0	0.0	102.2	103	2955	County	Rural Major Collector	57.2	30.0	6.7	0.0	93.9	20
771	County	Rural Local	57.2	45.0	0.0	0.0	102.2	98	2989	County	Rural Local	57.2	20.0	16.7	0.0	93.9	192
8909	County	Rural Minor Collector	57.2	45.0	0.0	0.0	102.2	105	10079	County	Rural Local	57.2	20.0	16.7	0.0	93.9	194
15659	County	Rural Local	57.2	30.0	14.8	0.0	102.0	106	7738	County	Rural Minor Collector	57.2	21.9	14.6	0.0	93.8	195
3296	County	Rural Local	57.2	32.5	12.0	0.0	101.7	107	9157	County	Rural Major Collector	57.2	32.9	3.7	0.0	93.7	21
11779	County	Rural Local	57.2	30.0	14.4	0.0	101.6	108	864	County	Rural Major Collector	57.2	20.7	15.7	0.0	93.5	22
3402	City	Rural Local	55.0	35.0	11.3	0.0	101.3	109	15837	County	Urban Minor Collector	57.2	23.0	13.3	0.0	93.5	196
2836	County	Rural Major Collector	57.2	30.7	13.3	0.0	101.3	10	6054	County	Rural Local	55.8	22.3	15.3	0.0	93.4	197
7302	County	Rural Minor Collector	57.2	30.5	13.5	0.0	101.2	110	1510	County	Rural Major Collector	57.2	36.2	0.0	0.0	93.4	23
1638	City	Urban Local	57.2	30.0	14.0	0.0	101.2	112	1092	County	Rural Local	57.2	20.2	16.0	0.0	93.4	198
292	City	Rural Local	57.2	30.0	14.0	0.0	101.2	111	5216	County	Rural Minor Collector	57.2	20.0	16.2	0.0	93.4	200
7192	County	Rural Major Collector	57.2	30.0	14.0	0.0	101.2	11	10595	County	Rural Local	57.2	20.0	16.2	0.0	93.4	199
4594	City	Urban Major Collector	57.2	34.9	8.9	0.0	101.1	12	1422	County	Rural Local	57.2	36.0	0.0	0.0	93.2	201
5342	County	Rural Minor Collector	57.2	30.0	13.8	0.0	101.0	113	9188	County	Rural Local	57.2	20.0	16.0	0.0	93.2	203
4260	County	Rural Local	55.1	30.0	15.9	0.0	101.0	114	11299	County	Rural Local	57.2	30.0	6.0	0.0	93.2	204
10438	County	Rural Local	56.5	30.0	14.4	0.0	100.9	115	12941	County	Rural Minor Collector	57.2	20.0	16.0	0.0	93.2	205
7665	County	Rural Minor Collector	57.2	30.0	13.7	0.0	100.9	116	101	County	Rural Local	57.2	30.0	6.0	0.0	93.2	202
5834	County	Rural Local	57.2	30.2	13.4	0.0	100.8	117	7382	County	Rural Minor Collector	57.2	20.0	15.9	0.0	93.1	209
15021	County	Rural Local	57.2	40.0	3.6	0.0	100.8	119	1435	County	Rural Minor Collector	57.2	20.0	15.9	0.0	93.1	208
10895	County	Rural Local	57.2	40.0	3.6	0.0	100.8	118	1698	County	Rural Local	57.2	20.0	15.9	0.0	93.1	206
12518	County	Rural Minor Collector	57.2	30.0	13.3	0.0	100.5	125	4235	County	Rural Local	57.2	20.0	15.9	0.0	93.1	207
3998	County	Rural Local	57.2	30.0	13.3	0.0	100.5	120	2611	City	Urban Minor Collector	57.2	23.1	12.5	0.0	92.8	210
8750	County	Rural Local	57.2	30.0	13.3	0.0	100.5	122	3623	City	Urban Local	40.0	35.0	17.8	0.0	92.8	211
7366	County	Rural Local	57.2	30.0	13.3	0.0	100.5	121	4950	County	Rural Local	57.2	20.0	15.6	0.0	92.8	212
7732	County	Rural Minor Collector	57.2	30.0	13.3	0.0	100.5	124	5705	County	Rural Local	57.2	20.0	15.6	0.0	92.8	213
9419	County	Rural Local	57.2	30.0	13.3	0.0	100.5	123	9478	County	Rural Minor Collector	57.2	20.0	15.6	0.0	92.8	214
6193	County	Rural Minor Collector	57.2	30.0	13.0	0.0	100.2	127	12736	County	Rural Minor Collector	57.2	20.0	15.6	0.0	92.8	215
7748	County	Rural Local	57.2	30.0	13.0	0.0	100.2	126	1312	City	Urban Local	57.2	20.0	15.6	0.0	92.8	216
1770	County	Rural Minor Collector	57.2	30.0	12.9	0.0	100.1	130	17016	County	Rural Local	57.2	20.0	15.5	0.0	92.7	217
20	County	Rural Minor Collector	57.2	30.0	12.9	0.0	100.1	129	11249	City	Urban Local	57.2	20.0	15.4	0.0	92.6	218
12273	County	Rural Local	57.2	30.0	12.9	0.0	100.1	128	10908	County	Rural Local	55.0	30.0	7.6	0.0	92.6	219
11860	County	Rural Major Collector	57.2	33.1	9.6	0.0	99.9	13	6757	County	Rural Local	57.2	20.0	15.3	0.0	92.5	220
3358	County	Rural Local	55.1	30.0	14.8	0.0	99.9	131	2494	County	Rural Local	57.2	20.0	15.2	0.0	92.4	221
6659	City	Urban Major Collector	57.2	30.0	12.6	0.0	99.8	15	4185	County	Rural Local	57.2	20.0	15.2	0.0	92.4	223
2122	County	Rural Local	57.2	35.0	7.6	0.0	99.8	132	1300	County	Rural Minor Collector	57.2	20.0	15.2	0.0	92.4	224
4334	County	Rural Major Collector	57.2	30.0	12.6	0.0	99.8	14	2623	County	Rural Local	57.2	20.0	15.2	0.0	92.4	222
6600	County	Rural Local	57.2	30.0	12.4	0.0	99.6	133	1602	County	Rural Local	57.2	35.0	0.0	0.0	92.2	230
5983	County	Rural Local	57.2	30.0	12.2	0.0	99.4	134	3577	County	Rural Minor Collector	57.2	35.0	0.0	0.0	92.2	237
348	City	Rural Local	57.2	30.7	11.4	0.0	99.3	135	1202	County	Rural Local	57.2	35.0	0.0	0.0	92.2	226

Table 7-2. Prioritized State-Owned Structures (201-250) (continued)

1316	City	Urban Local	40.0	55.0	0.0	0.0	95.0	183
3811	City	Rural Local	57.2	20.0	17.8	0.0	95.0	184
2401	County	Rural Local	57.2	37.8	0.0	0.0	95.0	185
1215	County	Rural Major Collector	57.2	37.5	0.0	0.0	94.7	19
3337	County	Rural Local	57.2	20.0	17.3	0.0	94.5	186
5676	County	Rural Local	57.2	20.6	16.7	0.0	94.5	187
1263	County	Rural Local	57.2	20.0	17.2	0.0	94.4	188
3655	County	Rural Minor Collector	57.2	20.4	16.6	0.0	94.2	189
437	County	Rural Minor Collector	57.2	20.8	16.2	0.0	94.2	190
3656	County	Rural Minor Collector	57.2	20.4	16.2	0.0	93.9	191
4041	County	Rural Local	57.2	20.0	16.7	0.0	93.9	193
2955	County	Rural Major Collector	57.2	30.0	6.7	0.0	93.9	20
2989	County	Rural Local	57.2	20.0	16.7	0.0	93.9	192
10079	County	Rural Local	57.2	20.0	16.7	0.0	93.9	194
7738	County	Rural Minor Collector	57.2	21.9	14.6	0.0	93.8	195
9157	County	Rural Major Collector	57.2	32.9	3.7	0.0	93.7	21
864	County	Rural Major Collector	57.2	20.7	15.7	0.0	93.5	22
15837	County	Urban Minor Collector	57.2	23.0	13.3	0.0	93.5	196
6054	County	Rural Local	55.8	22.3	15.3	0.0	93.4	197
1510	County	Rural Major Collector	57.2	36.2	0.0	0.0	93.4	23
1092	County	Rural Local	57.2	20.2	16.0	0.0	93.4	198
5216	County	Rural Minor Collector	57.2	20.0	16.2	0.0	93.4	200
10595	County	Rural Local	57.2	20.0	16.2	0.0	93.4	199
1422	County	Rural Local	57.2	36.0	0.0	0.0	93.2	201
9188	County	Rural Local	57.2	20.0	16.0	0.0	93.2	203
11299	County	Rural Local	57.2	30.0	6.0	0.0	93.2	204
12941	County	Rural Minor Collector	57.2	20.0	16.0	0.0	93.2	205
101	County	Rural Local	57.2	30.0	6.0	0.0	93.2	202
7382	County	Rural Minor Collector	57.2	20.0	15.9	0.0	93.1	209
1435	County	Rural Minor Collector	57.2	20.0	15.9	0.0	93.1	208
1698	County	Rural Local	57.2	20.0	15.9	0.0	93.1	206
4235	County	Rural Local	57.2	20.0	15.9	0.0	93.1	207
2611	City	Urban Minor Collector	57.2	23.1	12.5	0.0	92.8	210
3623	City	Urban Local	40.0	35.0	17.8	0.0	92.8	211
4950	County	Rural Local	57.2	20.0	15.6	0.0	92.8	212
5705	County	Rural Local	57.2	20.0	15.6	0.0	92.8	213
9478	County	Rural Minor Collector	57.2	20.0	15.6	0.0	92.8	214
12736	County	Rural Minor Collector	57.2	20.0	15.6	0.0	92.8	215
1312	City	Urban Local	57.2	20.0	15.6	0.0	92.8	216
17016	County	Rural Local	57.2	20.0	15.5	0.0	92.7	217
11249	City	Urban Local	57.2	20.0	15.4	0.0	92.6	218
10908	County	Rural Local	55.0	30.0	7.6	0.0	92.6	219
6757	County	Rural Local	57.2	20.0	15.3	0.0	92.5	220
2494	County	Rural Local	57.2	20.0	15.2	0.0	92.4	221
4185	County	Rural Local	57.2	20.0	15.2	0.0	92.4	223
1300	County	Rural Minor Collector	57.2	20.0	15.2	0.0	92.4	224
2623	County	Rural Local	57.2	20.0	15.2	0.0	92.4	222
1602	County	Rural Local	57.2	35.0	0.0	0.0	92.2	230
3577	County	Rural Minor Collector	57.2	35.0	0.0	0.0	92.2	237
1202	County	Rural Local	57.2	35.0	0.0	0.0	92.2	226

8.0 Conclusions

This project has extended the bridge deficiency metric developed in Project #930-661 to facilitate prioritization of bridge replacement and rehabilitation through a five year maintenance planning process for state-owned bridges. It also identified and defined the factor weights to be used in the locally-owned bridges. The goal was to define a repeatable process that captures local and county structures according to their purpose and rank these structures in a method that prevents unfair weighting of attributes.

State-owned bridge structures are based largely on standard designs, with few exceptions. Therefore having a single superset of state structures is a feasible approach when calculating a deficiency ranking. Local bridges differ greatly by the purpose for which they are constructed and therefore the loads and dimensions vary widely from structure to structure. The use of a single set of parameters to determine deficiency is not feasible for the local and county population. The developed algorithm's criteria and weight factors were adjusted by comparing the deficiency rankings against the judgment of experienced ALDOT engineers and bridge inspectors.

The methodology presented in this research has produced a reliable and repeatable process that will create a prioritized list of structures based on deficiency scores. The application of this methodology utilizing 2009 inventory data has been validated by ALDOT bridge management personnel as an acceptable method for determining bridge priorities. There is a need for increased granularity in the computed scores, but this is not feasible with the current data fields. Because currently available data items are highly correlated (dependent), adding data items to the model fails to add new information The system of sorting as described in section 7.2 of this report, Deficiency Value Tie Breaking, is able to support the need for granularity by sorting the data based on requirements outlined by ALDOT. The process presented is a viable alternative to increasing the variables in the model, while still capturing a structure's unique position within the inventory.

Project Benefits

Benefits of this project include:

- A bridge deficiency metric that provides a robust analytic study of the factors that impact bridge condition and their weighting coefficients.
- Standardization of the budget planning process across replacement and rehabilitation projects while accounting for potential variances between state-, county- and municipal-owned bridges.

- Increased integrity and reliability of data collected for forecasting and prioritization of bridge rehabilitation and replacement maintenance needs.
- A flexible maintenance planning scenario tool to assess the impact of replacement and rehab policy changes and service level targets.
- Effective use of FHWA funding to support bridge replacement and rehabilitation maintenance.

Future Research

The model to prioritize structures could be validated against the 2010 and 2011 databases to determine movement of structures as they progress toward the top of the list. A similar comparison was performed with the state owned structures and validates the process presented in the BER #547-39 report. The movement of structures from their planned year in 2007 to a planned period of 2006 when compared against 2009 data identified that prioritized structures were correctly being replaced and removed from the list. A similar investigation should be performed using this method to compare 2009 data to 2010 and 2011 data to determine if the approach is supported.

The research presented used a set of rules to determine Level of Service (Table 2-1). The grouping of structures based on functionality still contained a wide variety of structural characteristics. Determining if additional sub-setting of these groups is possible may assist in refining the model to capture more realistic deficiency scores and ensure that masking is not occurring by structures being compared outside of their functional requirements. Breaking the groups down into rural, urban, major, and minor (as listed in the database) may give additional insight for determining deficiency.

GIS will contribute to a set of alternative approaches with respect to geospatial location. A set of rules can take into account the location of a structure and its proximity to another adjacent structure, a structure along a shared route, or structure within a country or geographic region (e.g. division or district). Identifying these structures would support either a joining of jobs to take advantage of construction in the immediate area or to separate jobs so that several different areas may benefit from rehabilitation or replacement funding. This approach would view the structures as a true network instead of treating each item in the inventory independently.

The data base contains the latitude and longitude for most of the structures. Using GIS, many of the entries were found to be misrepresentative of the structure's actual location. A process to verify these locations, and correct them if necessary, would be required before the implementation of the above proposal.

9.0 References

Richardson, J. and Turner, D., *Development of Deficiency Point Algorithms for the Alabama Bridge Information Management System*, Bureau of Engineering Research Report #547-39, University of Alabama College of Engineering, 1991a, 49 pp.

Richardson, J., Turner, D., Hale, D., and Sharpe, S., Bridge Health Monitoring Metrics: Updating the Bridge Deficiency Algorithm, Alabama Department of Transportation Report #930-661, 2009, 83 pp.

Appendix A: ALDOT Bridge Replacement Program

Outline of Annual Operations *Last Revised: January 23, 2007*

1. Establish Bridge Replacement Prioritization Committee. Members to include:
   a. Chief Engineer
   b. Asst Chief Eng., Ops.
   c. Maintenance Engineer
   d. Bridge Engineer
   e. Office Engineer
   f. Planning and Multimodal
   g. Asst. Maintenance Engineer-Bridges
   h. FHWA (ex-officio)

2. Establish bridge replacements period.

3. Bridge replacement budgets are established for each fiscal year of replacement period.
   a. Office Engineer provides Maintenance Bureau the funds available each fiscal year of the programmed period.
   b. Maintenance Bureau estimates amount of BR funding needed for Bridge Painting Program for each fiscal year.
   c. Chief Engineer approves BR funds to be set aside for Bridge Painting.
   d. Remainder of BR funds available for replacement projects.

4. A prioritized list of bridges to be replaced is produced by the Maintenance Bureau.
   a. Initial list is produced by ABIMS with bridges ranked by their deficiency score. Higher numbers represent bridges in worse shape; lower numbers represent bridges in better shape.
   b. Bridges are reviewed by the Maintenance Bureau for compliance with HBR eligibility requirements.
   c. Initial bridge priorities are reviewed by the Maintenance Bureau and may be adjusted for reasons that include the following:
      i. Bridges that have an adverse impact on ALDOT's ability to issue overweight permits are raised in priority,
      ii. Bridges that can be removed are raised in priority. An example is a bridge that overpasses an abandoned rail line,
      iii. Bridges that do not meet HBR eligibility are reduced in priority.
   d. Maintenance Bureau assigns bridges to each fiscal year of replacement period.

5. Prioritized list from Step 4 is distributed to the Divisions, Bridge Bureau, Design Bureau (especially Environmental) and M&T.
   a. Divisions are asked to review replacement estimates and develop more refined estimates where appropriate.
   b. Each Division is asked to submit comments and recommendations for changes in proposed prioritization.

6. Maintenance Bureau and Office Engineer adjust assignment of bridges to fiscal years based on:
   a. adjusted replacement cost estimates
   b. Comments and recommendations from Divisions
   c. Comments and recommendations from Bridge, Design and M&T Bureaus

7. Advance copy of adjusted prioritized list is provided to committee members for review.

8. Bridge Replacement Prioritization Committee meets to:
   a. Make own recommendations for changes as needed.
   b. Approve prioritized list

9. Maintenance Bureau produces final prioritized list.
   a. Bridges for Year 1 through Year 3 are signed off by Chief Engineer and Director
   b. Lists for all years are distributed.

10. Subsequent changes to Year 1 through Year 3 must be approved by the Bridge Prioritization Committee and signed off by the Chief Engineer and Director.

Appendix B: Principles of Algorithm Development (from ALDOT #930-661 Final Report)

The following are the bridge deficiency principles that evolved during algorithm's development.

- Principle: One major deficiency should outweigh several minor deficiencies.

  - Rational: Major deficiencies have an urgency that minor deficiencies do not. Therefore, a bridge with one major deficiency should be ranked higher than a bridge with several minor deficiencies.

  - Implementation: Deficiency points are assigned aggressively for the major deficiencies to create a "gap" between the major and the intermediate deficiencies. For example, a bridge with a posted maximum load of 10 tons (restricted to all bus and truck traffic) is assigned 40 deficiency points while a bridge with a condition rating of four, no shoulders, and a vertical clearance of only 16.5 feet is assigned 35 deficiency points.

- Principle: Load ratings and condition ratings are the most meaningful indicators of bridge deficiency.

  - Rational: Both of these data items are based on a synthesis of many pieces of information by an experienced load rating engineer or bridge inspector. And both data items can trigger ALDOT actions: low load ratings lead to bridge posting, and low condition ratings (condition rating of three or four) lead to notification of superiors and other actions.

  - Implementation: Deficiency points are only assigned to bridges with load ratings and condition ratings that trigger ALDOT actions: i.e. for posted bridges and for condition ratings equal to three or four. The majority of the possible deficiency points are assigned to these two data items (up to 40 points for load ratings and up to 60 points (rare) for poor condition ratings).

- Principle: ADT should affect deficiency points in moderation.

  - Rational: Take the case of two bridges with identical characteristics and therefore equal deficiency points. One bridge has very high traffic and the other only average traffic. Replacement of the high-traffic bridge is more urgent than replacement of the moderate traffic bridge, so the high-traffic bridge should therefore be assigned more deficiency points.

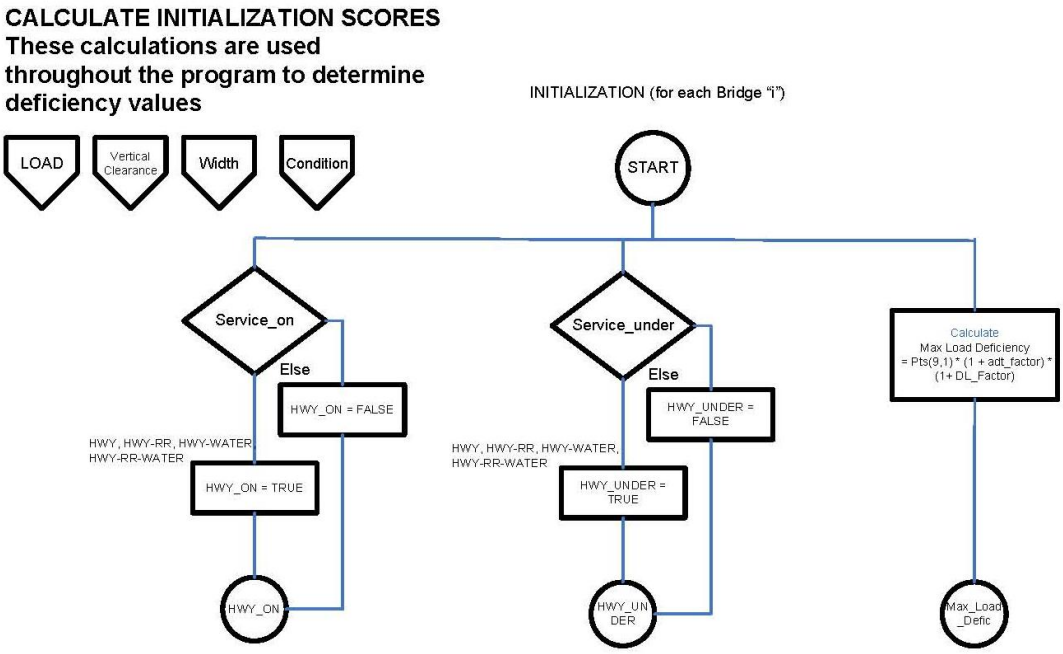
    But, the ADT factor should not be so large that it causes a high-traffic bridge with a minor deficiency to outrank a low-traffic bridge with a major deficiency.

    More controversial is the assertion that a low-traffic bridge should not be penalized, i.e. be assigned fewer deficiency points than an identical moderate-traffic bridge. Part of the argument supporting this assertion is that bridges on the state highway system should

provide a minimum level of service, no matter what their traffic volume. Another part of the argument is that ADT does not reflect the type of traffic. For example a low-traffic bridge could carry school buses or log trucks, both important to the local community.

- Implementation: The ADT factor is rather small, increasing the deficiency points for high-traffic bridges by a maximum of 30%. The ADT factor is based on the percent rank of a bridge's ADT in the population of all state-owned bridges. Using percent rank as the basis for the ADT factor serves two purposes: (1) bridge deficiency rankings are adjusted based on traffic volume *relative to the population under consideration* and (2) there is no need to update the factor as the bridge population changes. (See ***Dynamic Adjustment*** in ALDOT #930-661, Chapter 5.).

Appendix C: Flow Chart of Deficiency Algorithm (consistent with #930-661 Appendix B)

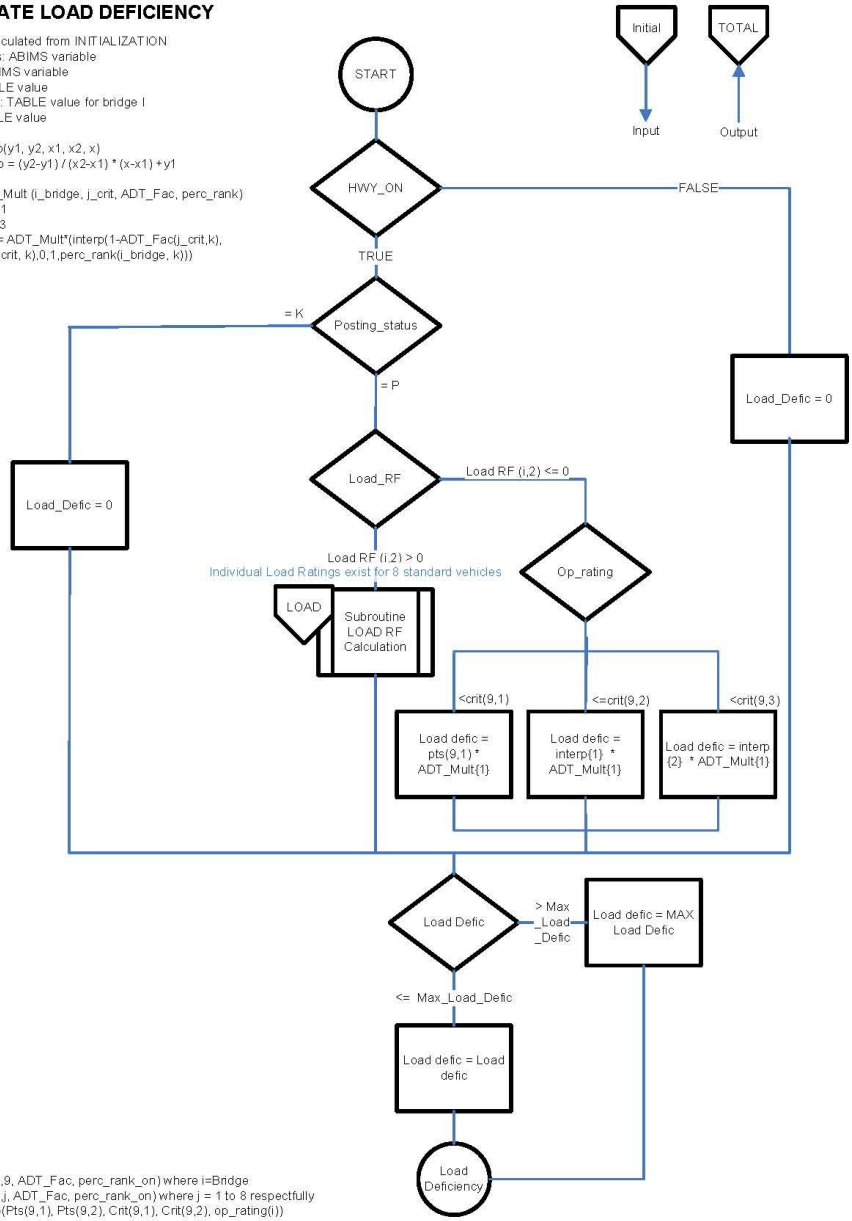


CALCULATE LOAD DEFICIENCY

HWY_ON : calculated from INITIALIZATION
Posting_status: ABIMS variable
Op_rating: ABIMS variable
Crit(A,B): TABLE value
Load RF (A,B): TABLE value for bridge I
Pts(A,B): TABLE value

Function Interp(y1, y2, x1, x2, x)
Interp = (y2-y1) / (x2-x1) * (x-x1) + y1

Function ADT_Mult (i_bridge, j_crit, ADT_Fac, perc_rank)
ADT_Mult = 1
For K=1 to 3
ADT_Mult = ADT_Mult*(interp(1-ADT_Fac(j_crit,k), 1+ADT_Fac(j_crit, k),0,1,perc_rank(i_bridge, k)))
Next K

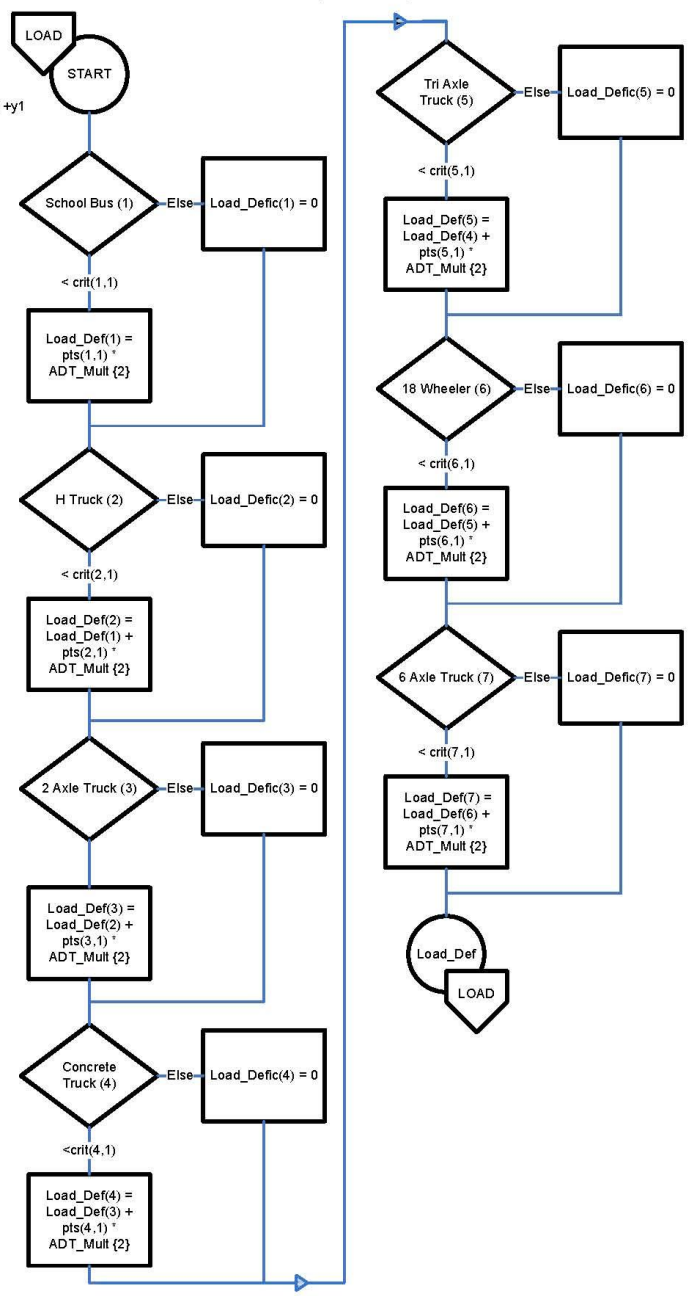


ADT_Mult{1} = {i,9, ADT_Fac, perc_rank_on) where i=Bridge
ADT_Mult{2} = {i,j, ADT_Fac, perc_rank_on) where j = 1 to 8 respectfully
Interp{1} = Interp(Pts(9,1), Pts(9,2), Crit(9,1), Crit(9,2), op_rating(i))
Interp{2} = Interp(Pts(9,2), Pts(9,3), Crit(9,2), Crit(9,3), op_rating(i))

CALCULATE LOAD (Subroutine for LOAD RF for 7 vehicles) called by LOAD DEFICIENCY

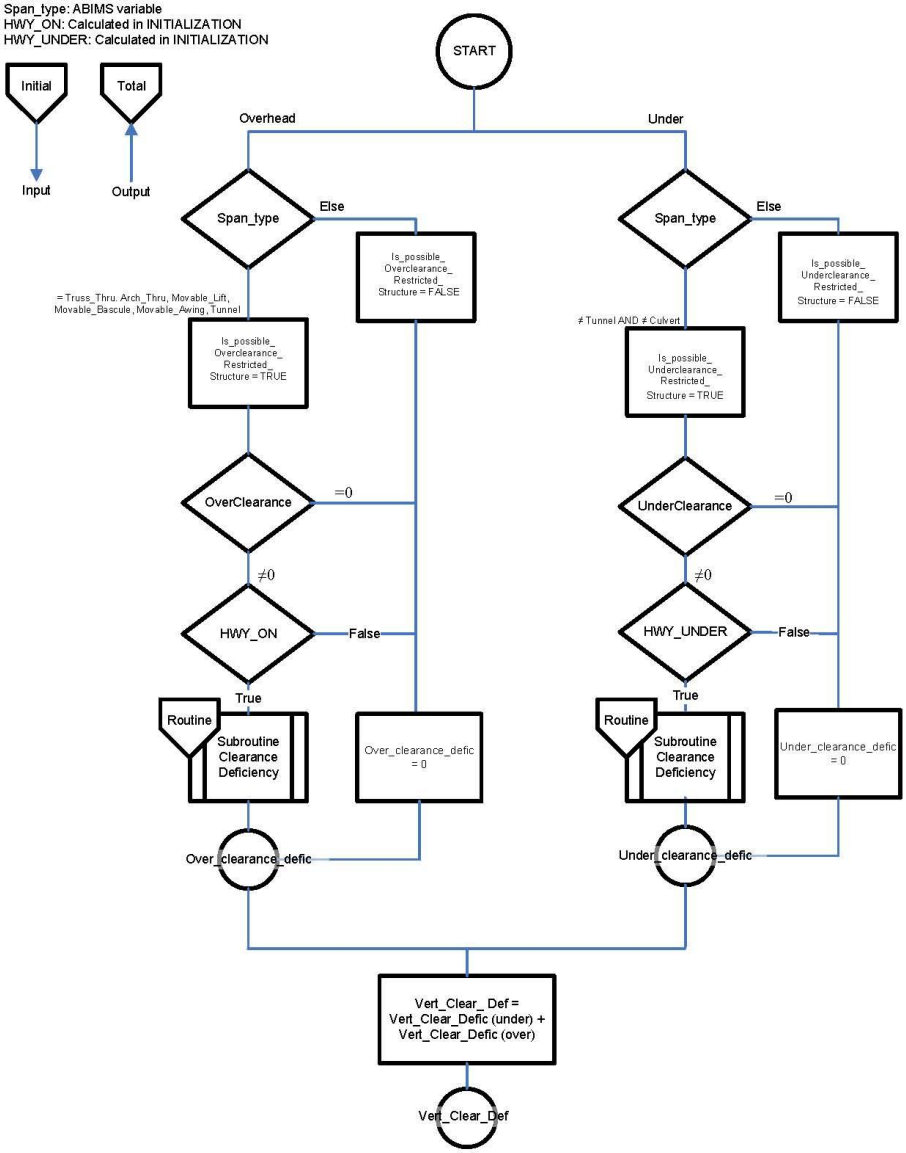
Crit(A,B): TABLE value

Function Interp(y1, y2, x1, x2, x)
Interp = (y2-y1) / (x2-x1) * (x-x1) +y1



CALCULATE TOTAL CLEARANCE DEFICIENCY
Calls SUBROUTINE CLEARANCE DEFICIENCY

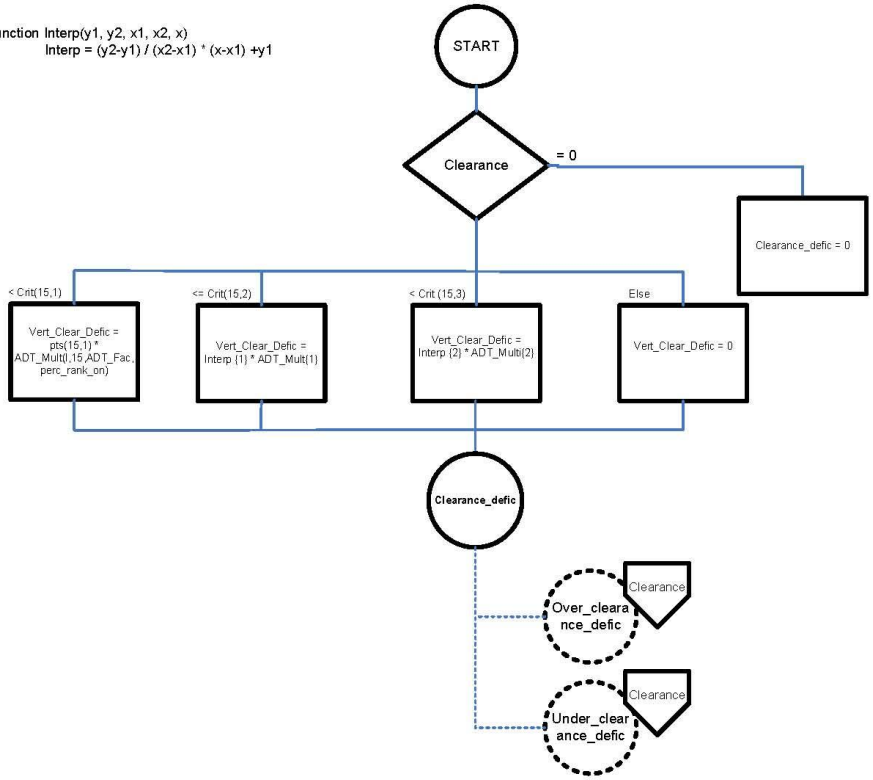
Clearance: ABIMS variable
Span_type: ABIMS variable
HWY_ON: Calculated in INITIALIZATION
HWY_UNDER: Calculated in INITIALIZATION



CALCULATE CLEARANCE DEFICIENCY (Subroutine for "On" and "Under") called by TOTAL CLEARANCE DEFICIENCY

Clearance: ABIMS variable
Crit(A,B): TABLE value

Function Interp(y1, y2, x1, x2, x)
Interp = (y2-y1) / (x2-x1) * (x-x1) +y1



Dependant on which clearance was calculated

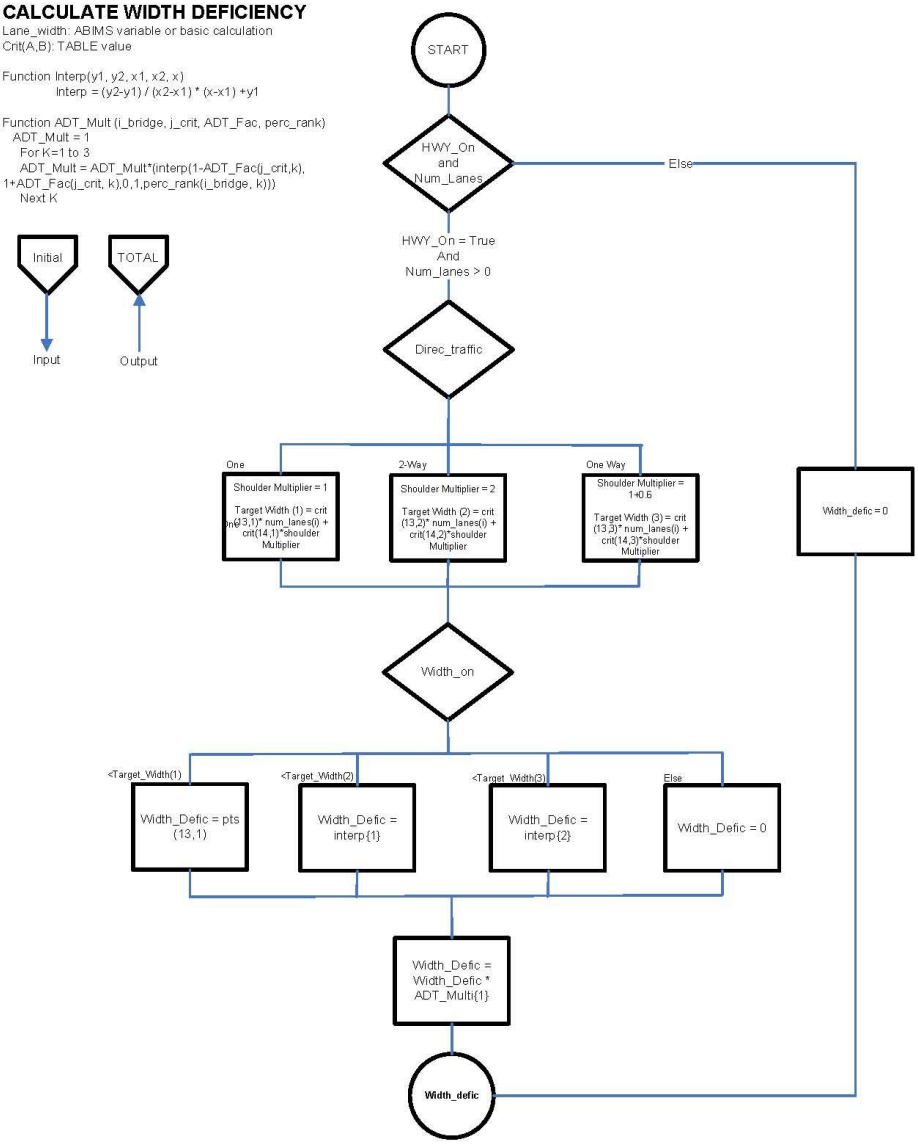
ADT_Mult{1} = {i,15, ADT_Fac, perc_rank_on)
ADT_Mult{2} = {i,15, ADT_Fac, perc_rank_on)
Interp{1} = Interp(Pts(15,1), Pts(15,2), Crit(15,1), Crit(15,2), Overclearance(i))
Interp{2} = Interp(Pts(15,2), Pts(15,3), Crit(15,2), Crit(15,3), Overclearance(i))

CALCULATE WIDTH DEFICIENCY

Lane_width: ABIMS variable or basic calculation
Crit(A,B): TABLE value

```
Function Interp(y1, y2, x1, x2, x)
        Interp = (y2-y1) / (x2-x1) * (x-x1) +y1

Function ADT_Mult (i_bridge, j_crit, ADT_Fac, perc_rank)
  ADT_Mult = 1
   For K=1 to 3
   ADT_Mult = ADT_Mult*(interp(1-ADT_Fac(j_crit,k),
1+ADT_Fac(j_crit, k),0,1,perc_rank(i_bridge, k)))
   Next K
```



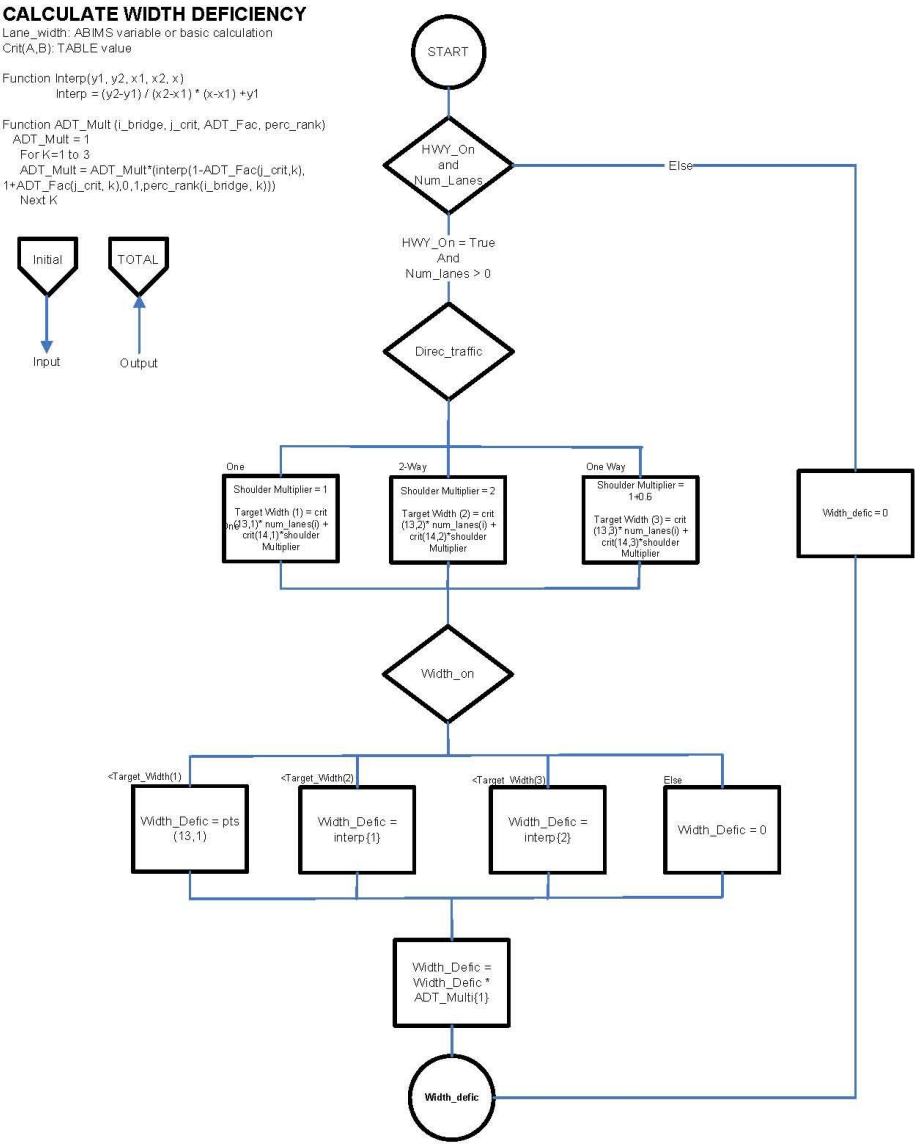
ADT_Mult{1} = {i,13, ADT_Fac, perc_rank_on)
Interp{1} = Interp(Pts(13,1), Pts(13,2), Target_Width(1), Target_Width(2), Width_on(i))
Interp{2} = Interp(Pts(13,2), Pts(13,3), Target_Width(2), Target_Width(3), Width_on(i))

CALCULATE WIDTH DEFICIENCY

Lane_width: ABIMS variable or basic calculation
Crit(A,B): TABLE value

```
Function Interp(y1, y2, x1, x2, x)
        Interp = (y2-y1) / (x2-x1) * (x-x1) +y1

Function ADT_Mult (i_bridge, j_crit, ADT_Fac, perc_rank)
  ADT_Mult = 1
   For K=1 to 3
   ADT_Mult = ADT_Mult*(interp(1-ADT_Fac(j_crit,k),
1+ADT_Fac(j_crit, k),0,1,perc_rank(i_bridge, k)))
   Next K
```

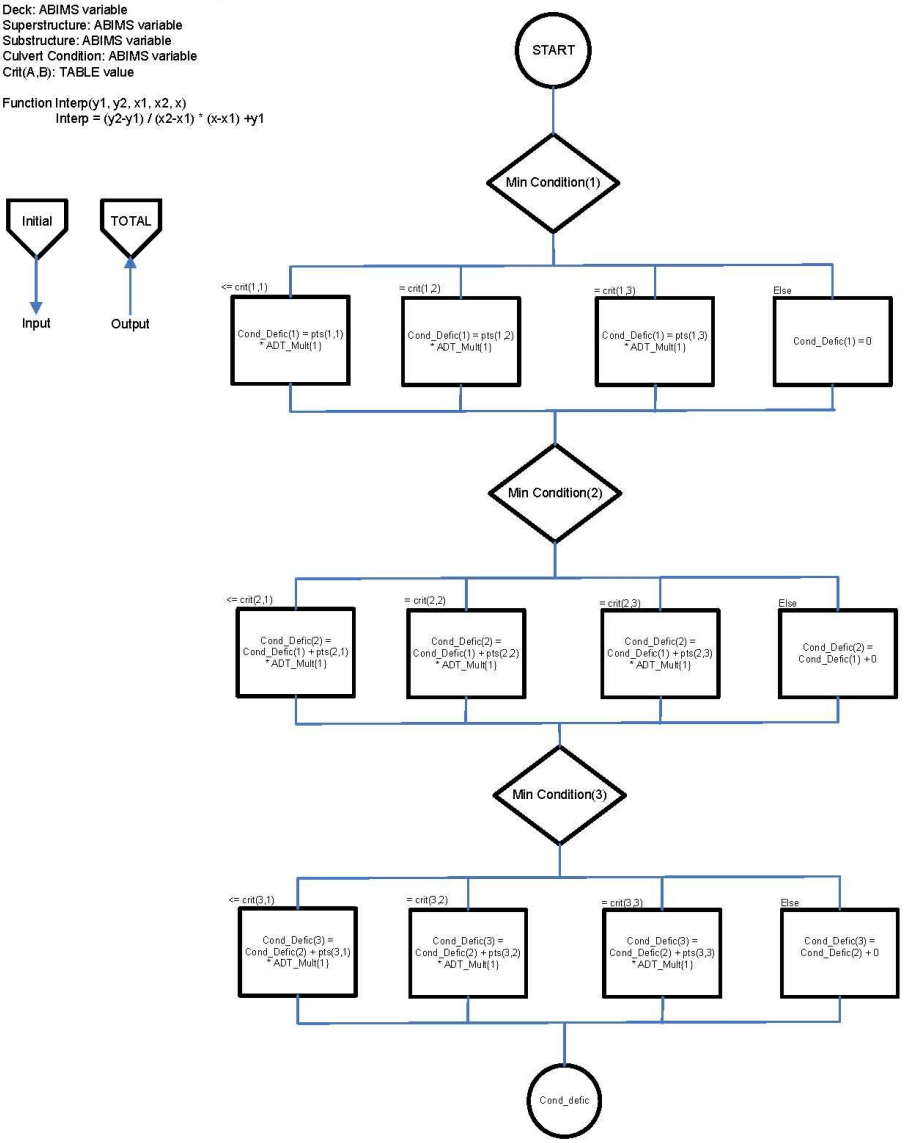


ADT_Mult{1} = {i,13, ADT_Fac, perc_rank_on)
Interp{1} = Interp(Pts(13,1), Pts(13,2), Target_Width(1), Target_Width(2), Width_on(i))
Interp{2} = Interp(Pts(13,2), Pts(13,3), Target_Width(2), Target_Width(3), Width_on(i))

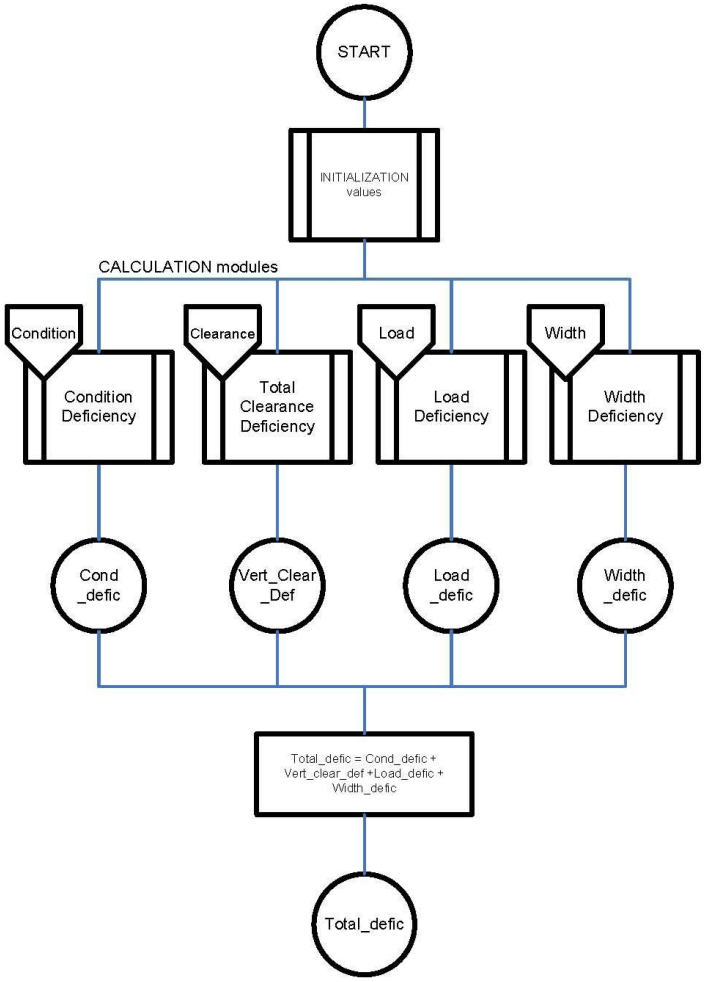
CALCULATE CONDITION DEFICIENCY

Deck: ABIMS variable
Superstructure: ABIMS variable
Substructure: ABIMS variable
Culvert Condition: ABIMS variable
Crit(A,B): TABLE value

Function Interp(y1, y2, x1, x2, x)
Interp = (y2-y1) / (x2-x1) * (x-x1) +y1



ADT_Mult{1} = {i,j, ADT_Fac, perc_rank_on)
Where j represents (min condition 1,2,3 respectfully)

CALCULATE TOTAL DEFICIENCY

Calculation Module Condition Deficiency
Calculation Module Clearance Deficiency
Calculation Module Load Deficiency
Calculation Module Width Deficiency