Bridge Health Monitoring Metrics: Updating the Bridge Deficiency Algorithm

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16. Abstract

As part of its bridge management system, the Alabama Department of Transportation (ALDOT) must decide how best to spend its bridge replacement funds. In making these decisions, ALDOT managers currently use a deficiency algorithm to rank bridges that are the most deficient and in need of replacement. The current algorithm is outdated and needs to be revised to reflect modern bridge performance criteria.

UTCA researchers established a new set of performance criteria that reflect modern ALDOT practice, set performance goals for each criterion, and assigned importance factors to the criteria. The updated bridge deficiency algorithm was evaluated by comparing lists of bridges ranked in order of decreasing deficiency against the judgment of experience division bridge inspectors, the 194 bridges selected for replacement in the 2007 through 2011 bridge replacement program, and a similar list produced by the 1991 deficiency algorithm.

The lists of deficient bridges produced by the new algorithm showed excellent agreement with each of the above. This new bridge deficiency algorithm would be an asset to ALDOT in developing standardized budget planning across the range of bridge treatments: preventive maintenance, rehabilitation, and replacement.

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Executive Summary

The Alabama Department of Transportation (ALDOT) contracted The University of Alabama (UA) to update the algorithm that ranks bridges according to deficiency. This project (ALDOT #930-661) began in August 2006 and finished in April 2008. The goal of this project was to develop a “common sense” algorithm that used simple functions to calculate bridge relative deficiency based on physical bridge characteristics represented in the bridge 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.

The contents of this report are as follows. First, the original deficiency algorithm (1991 algorithm) is reviewed since the updated algorithm builds on the original and the lessons learned using it. Next, the updated algorithm is presented: specifically, the functions that compare bridge characteristics in the database against deficiency criteria and assign deficiency points according to the weight factors. The criteria are organized into a matrix, as are the weight factors and adjustment factors to facilitate future adjustment of the algorithm (Figure C-1).

In the third chapter of this report, the new algorithm is evaluated by comparing lists of bridges ranked in order of decreasing deficiency against

- the judgment of experienced division bridge inspectors,
- the 194 bridges selected for replacement in the 2007 through 2011 bridge replacement program, and
- a similar list produced by the 1991 deficiency algorithm.

The lists of deficient bridges produced by the new algorithm showed excellent agreement with each of the above. Where discrepancies occurred, there was almost always a logical explanation.

Chapter 4 explains the process used to develop the algorithm. A graphical interface was developed to quickly adjust the criteria and weight factors and to assess the impact on the deficiency rankings. A detailed list of deficient bridges was also created for spot checking the calculations.

Chapter 5 describes a sensitivity analysis of the weight factors using different scenarios. This analysis was used to determine the range of values that best differentiated each type of deficiency without overshadowing other deficiencies.

And finally, Chapter 6 presents conclusions and recommendations.

Appendix A contains a decision tree of the algorithm that presents the calculation procedures of the algorithm in an easy-to-follow manner. Appendix B contains a flow chart of the algorithm, and Appendix C shows the source code for the algorithm.

1.0 1991 Deficiency Algorithm

The original deficiency algorithm was developed in 1991 by Richardson and Turner (1991a, 1991b). The algorithm compared certain characteristics for each bridge recorded in the state bridge database against performance criteria. Bridges not meeting the performance criteria were assigned "deficiency points." The output of the algorithm was a list of bridges ranked from most to least deficient. The bridge deficiency rankings were used to help select bridges for replacement.

In developing the 1991 algorithm, the project team

- reviewed procedures used by other states,
- developed criteria appropriate for Alabama bridges,
- formulated an algorithm to calculate deficiency points, and
- validated the algorithm results against the judgment of experienced ALDOT engineers.

Each of these tasks is reviewed briefly in the following sections.

Review of Other States' Procedures

Using data in the bridge database, the algorithm compared certain bridge characteristics against goals. These goals, called level of service goals, were set so that bridges meetings these goals would provide highway users with an acceptable level of service. Four categories of goals were developed that were considered to affect the level of service provided to users. A review of level of service goals of other states showed similar goal categories, although the relative importance of the goals varied from state to state. (See Table 1-1.)

Table 1-1. Goal Categories for Calculating Bridge Level of Service (Richardson and Turner, 1991a)

Goal Category	**- - - - - - - Relative Importance (% of Total Deficiency) - - - - - -**				
	North Carolina	Virginia	Nebraska	Kansas	Alabama
Load Capacity	70	30	50	17	40
Condition	6	46	10	55	40
Width	12	12	12	28	10
Vertical Clearance	12	12	28	0	10

Alabama Deficiency Criteria

The deficiency criteria selected for Alabama are shown in the last column of Table 1-1. A bridge's load capacity and vertical clearance affect the level of service provided to truck traffic. Trucks exceeding the posted load limit or vertical clearance must detour around the bridge. The bridge width affects the level of service provided to both car and truck traffic. Finally, condition ratings indirectly affect the level of service because bridges in very poor condition have an increased likelihood of being closed.

In addition to the four categories described above, another category called special condition points was added to accommodate situations not depicted in the bridge database. For example, if a particular bridge was the only bridge on a route in poor condition, it might be a candidate for special condition points. These points (typically between 30 and 40) were assigned by the State Bridge Maintenance Engineer in consultation with division engineers and bridge inspectors.

The specific goals for three of the four goal categories were assigned in tiers according to the level of service expected from the highway over the bridge. (See Table 1-2.) Bridges carrying routes with higher functional classifications were assigned more stringent goals.

Table 1-2. Goals for Load Capacity, Width, and Vertical Clearance for Each of Five Functional Classifications

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

*Width goals are for two-way traffic

Specific goals for the condition goal category can be inferred from the scheme assigning deficiency points for the condition ratings of the major bridge components. (See Table 1-3.) Deficiency points were assigned if the condition rating for the deck, superstructure, or substructure was less than a "5." When a bridge inspector assigns a bridge component a condition rating of "4," he or she must write a letter to the State Maintenance Engineer explaining the situation. Also, the load capacity of the bridge should be re-analyzed and if this is not possible, the load capacity should be set equal to half of the design load. When a condition rating of "3" is assigned to a bridge, the bridge should be load posted at three tons and inspected every three months.

Table 1-3. Deficiency Points for Poor Condition Ratings

Condition Rating	- - - - - - - - Deficiency Points - - - - - - - -		
	Deck	Superstructure	Substructure
4	5	10	15
3	10	20	30
<=2	20	40	60

Bridge owners occasionally opt to replace a single component of a bridge (e.g. a timber deck in poor condition supported by a superstructure and substructure in good condition). Since a deck is the least costly to replace, it received the fewest deficiency points. (See Table 1-3.) Replacement of the substructure generally involves complete bridge replacement; therefore, this component was allocated the most deficiency points.

Algorithm to Calculate Deficiency Points

The load capacity and vertical clearance deficiency points were multiplied by an average daily traffic (ADT) factor and by a detour length factor, and the width deficiency points were multiplied by an ADT factor. The specific functions of the algorithm are presented in a later section of this report as part of a comparison with the new deficiency algorithm.

The 1991 algorithm calculated the total deficiency points of each bridge in the database to form a ranked list of the most-deficient bridges in the state. The total deficiency points were calculated as the sum of the deficiency points in each category. The deficiency points for each category could not exceed the values shown in the last column of Table 1-1, and the total deficiency points could not exceed 100.

Validation of Algorithm

The 1991 algorithm was validated by comparing the ranked list of deficient bridges against similar lists produced by experienced ALDOT and county engineers and bridge inspectors. Issues raised during the discussions with local engineers and bridge inspectors included:

- the ADT factor should be decreased
- the inventory rating (the measure of load capacity used by the 1991 algorithm) did not reflect the effects of strengthening; perhaps only load-posted bridges should receive deficiency points
- especially narrow bridges should receive more deficiency points
- bridges with scour problems should receive deficiency points
- the ADT numbers for county routes were not always accurate

The ADT factor was decreased, which addressed the first and fifth issue above. The other issues were not addressed in the 1991 algorithm.

Performance of the 1991 Algorithm

ALDOT engineers and managers used the ranked list of deficient bridges, as calculated by the deficiency algorithm, to help select the state-owned bridges recommended for replacement. The following shortcomings were observed by ALDOT engineers and managers:

- Not enough deficiency points were assigned to very narrow bridges.
- Deficiency points were not assigned to culverts.
- Load capacity was represented by inventory rating, but bridges are posted for load restrictions based on operating ratings.
- The goals for load capacity, width and vertical clearance were not stringent enough.
- The goals and weight factors should be easy to update (without modifying the source code of the program).
- The deficiency equations were not intuitive (i.e. simple and based on a bridge's physical characteristics).

2.0 New Algorithm

Each of the issues listed on the preceding page were addressed in the new deficiency algorithm described below. The new algorithm was designed specifically for state-owned bridges, because the population of state-owned bridges differs significantly from county and municipal bridges, and because the processes for selecting bridges for replacement are very different at the state vs. the county level. A follow-on project has been proposed for developing an algorithm specifically for "locally-owned" bridges (county, city, etc.).

The new deficiency algorithm was developed based on the concept of bridge utility. Bridges with characteristics causing loss of utility for the highway user should be assigned deficiency points. The project team reviewed all of the 294 fields in the bridge database and selected four fields as the best measures of bridge utility. (See Table 2-1.) Although these fields represent similar criteria as those used for the 1991 algorithm (Table 1-1), the actual deficiencies are calculated very differently.

Table 2-1. 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 where they must be closed.

The relative weights of the deficiency categories shown in Table 2-1 are similar to the relative weights used for the 1991 algorithm. (See Table 1-1.) For both algorithms, the load capacity ratings and the 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 greater meaning.

The actual relative weights were selected based on several analyses (described in Chapter 4 of this report) 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 the next five sections:

- Load Capacity Deficiency Points
- Condition Deficiency Points
- Width Deficiency Points
- Vertical Clearance Deficiency Points
- ADT, ADTT, and Detour Length Factors

The corresponding functions from the 1991 algorithm are also shown for comparison purposes.

For the load capacity, width and vertical clearance deficiencies, the functions are all piece-wise linear with four segments, as shown in Figure 2-1. Segments 1 and 4 are always horizontal (constant deficiency): the maximum deficiency points are assigned if the bridge characteristic is below the “minimum acceptable” value, and zero deficiency points are assigned if the bridge characteristic is above the “desirable” value. For bridge characteristics between the minimum acceptable and the desirable, deficiency points are calculated by interpolating on the appropriate segment.

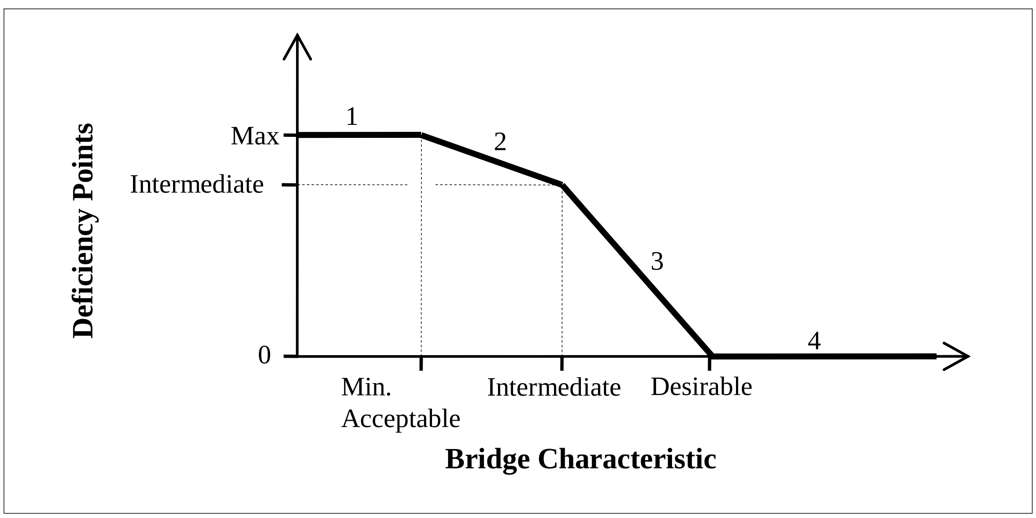


Figure 2-1. Typical deficiency point function.

Load Capacity Deficiency Points

Truck traffic is only affected by reduced load capacity of a bridge if the bridge is load-posted. Therefore, only bridges posted for load (Posting Status = "P" in the bridge database) are assigned load capacity deficiency points in the new algorithm.

Load restrictions are placed on a bridge if bridge load rating analyses indicate that the operating rating (maximum permissible load) of the bridge is less than the legal load in the state of Alabama. Alabama calculates the maximum safe permissible load of a bridge for eight different vehicle configurations, shown in Figure 2-2 along with the maximum legal gross weight for each vehicle. The load rating factor (RF) is the ratio of the maximum safe load divided by the maximum legal gross vehicle weight. Most state-owned bridges have been load rated, and this information is available in the bridge database.

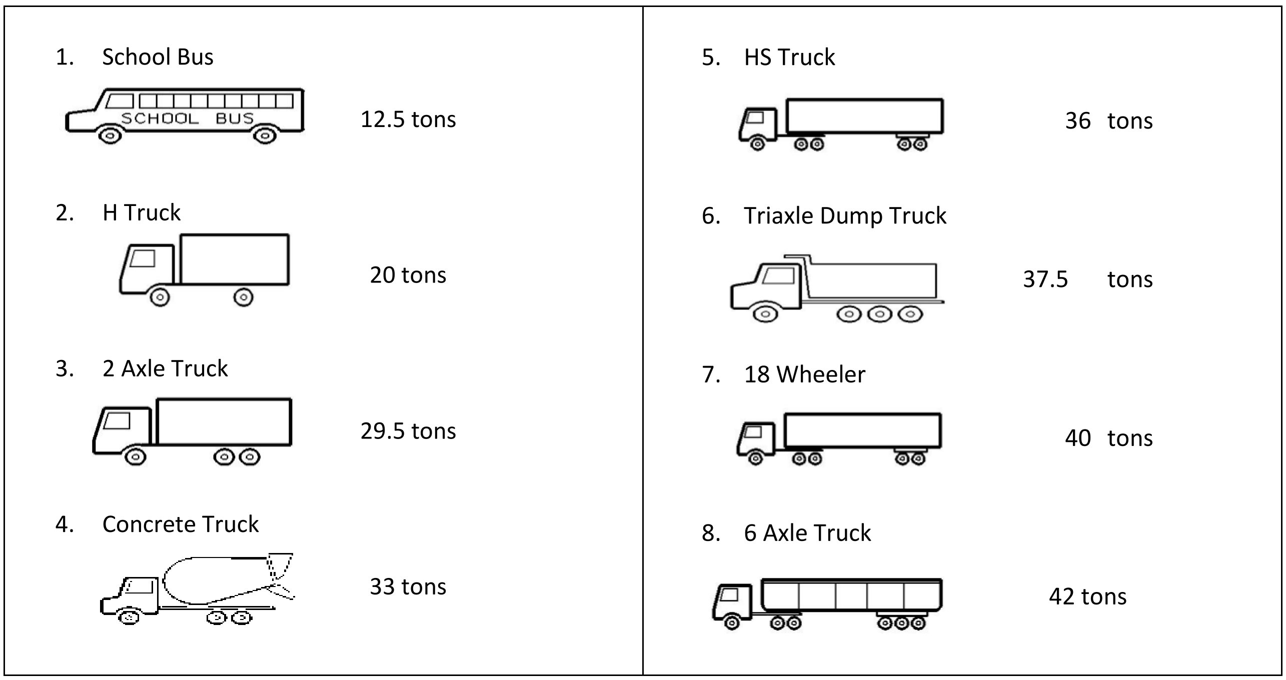


Figure 2-2. Maximum legal gross vehicle weights in Alabama.

Bridges that have not been load rated are assigned deficiency points based on the operating rating. The operating rating is specified by the federal government to be the safe permissible load for the HS Truck configuration. The inventory rating, by comparison, is specified to be the HS load that can be applied to a bridge for an indefinite period of time. The inventory rating of a bridge is approximately 0.75 of the operating rating. The inventory rating is used in the formula to calculate the sufficiency rating for a bridge (which controls eligibility for federal replacement funding). The operating rating is used to determine whether a bridge should be load posted, and is therefore the appropriate rating factor to use for assigning load capacity deficiency points.

Deficiency points are assigned to a bridge if the rating factors for certain load rating vehicles are less than one (Table 2-2). Load deficiency points are accumulated for each rating factor less than one, up to a maximum of 40 points.

Table 2-2. Load Deficiency Points, ADTT Factor, and Detour Factor Assigned for Each Load Rating Vehicle

Load Rating Vehicle	Deficiency Points if RF < 1	ADTT Factor	Detour Factor
School Bus	30		x
H Truck	0		
Two-Axle Truck	20	x	x
Concrete Truck	0		
HS Truck	0		
Triaxle Dump Truck	10		x
18-Wheeler	20	x	x
Six-Axle Truck	5		x
Max Load Deficiency Points = 40			

No deficiency points were assigned for the H Truck and the HS Truck since these are AASHTO design vehicles, and the Two-Axle Truck and 18-Wheeler are similar vehicles (respectively) and are more appropriate for Alabama. Also, no deficiency points were assigned for the Concrete Truck since the rating factor for this truck is usually similar to the rating factor for the Triaxle Dump Truck.

It was assumed that most of the truck traffic on state highways consisted of either Two-Axle Trucks or 18-Wheelers. As a partial justification, weigh-in-motion data for I-20/59 near Bucksville is shown in Figure 2-3. The FHWA vehicle classes are shown in Figure 2-4. The Two-Axle Trucks and 18-Wheelers were each assigned 20 deficiency points. These deficiency points will be multiplied by factors related to the average daily truck traffic (ADTT) and the detour length for the bridge.

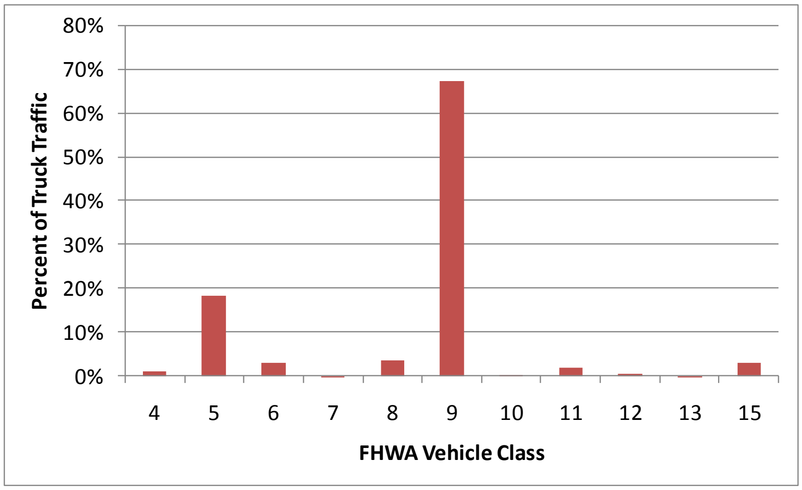


Figure 2-3. Distribution of truck types for I-20/59 near Bucksville.

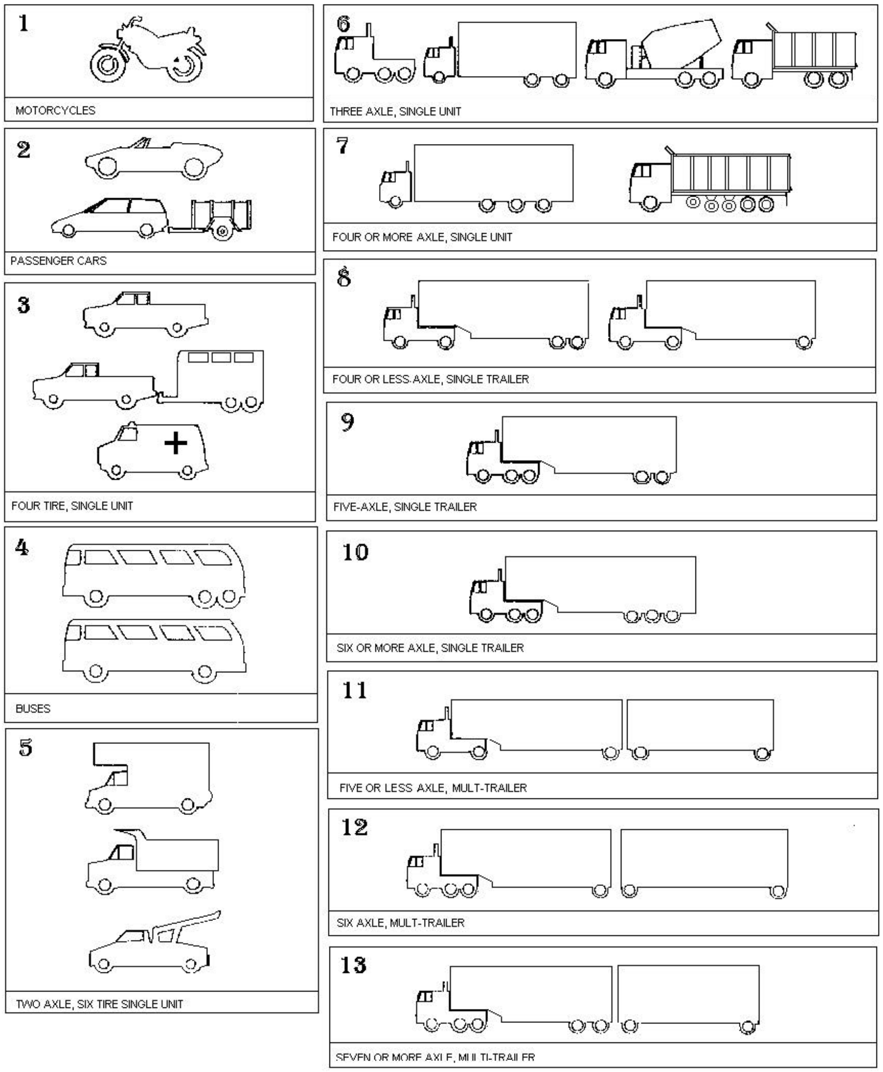


Figure 2-4. FWHA vehicle classification scheme.

The School Bus, the Triaxle Dump Truck, and the Six-Axle Truck were assigned 30, 10, and five deficiency points, respectively. These deficiency points will not be multiplied by the ADTT factor, since these vehicles represent a small percentage of truck traffic, but will be multiplied by the detour factor.

If load ratings for the eight rating vehicles are not available in the bridge database, then up to 40 load capacity deficiency points are assigned using the operating rating as illustrated in Figure 2-5, which also shows the 1991 algorithm function for comparison. The deficiency points are then multiplied the ADTT factor and the detour length factor.

Load deficiency points as calculated by the 1991 and by the new algorithm are compared in Table 2-3. The 1991 algorithm assigns deficiency points to many more bridges, due to its use of the more conservative inventory rating and its disregard of the posting status. Also, the 1991 algorithm enforces a maximum of 40 load deficiency points *after* the ADT and detour factors are applied; whereas the new algorithm applies the maximum of 40 load deficiency points *before* the ADT and detour factors are applied.

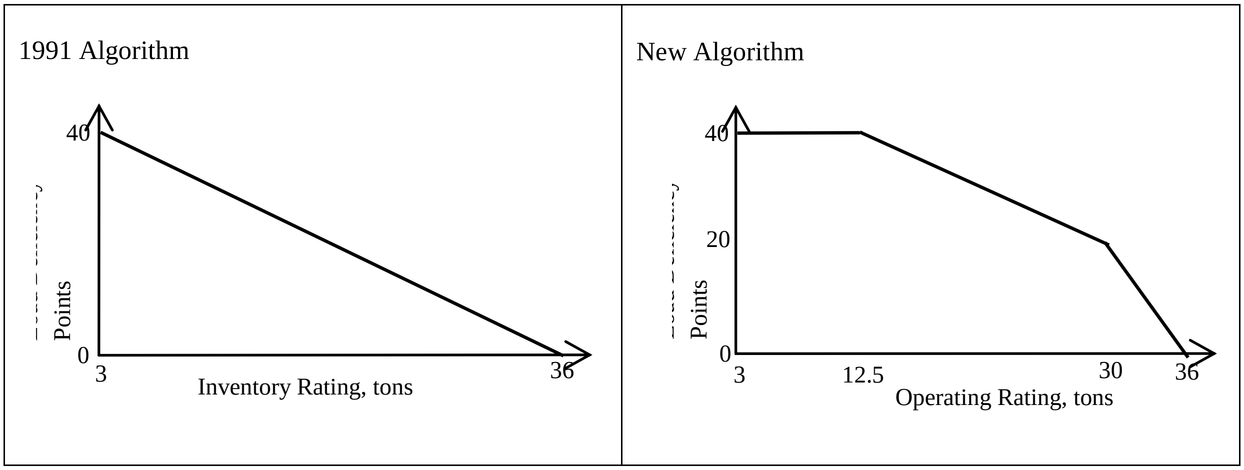


Figure 2-5. Load capacity deficiency points calculation: 1991 algorithm vs. new algorithm.

Table 2-3. Distribution of Bridges with Load Deficiency Points: 1991 Algorithm vs. New Algorithm

Load Deficiency Points	- - - - - - - - Number of Bridges - - - - - - - -	
	1991 Algorithm	**New Algorithm**
5	63	0
10	56	0
15	91	0
20	90	0
25	67	0
30	79	0
35	65	0
40	323	0
45	0	1
50	0	0
55	0	0
60	0	8
Sum	834	9

Condition Deficiency Points

The 1991 algorithm assigned condition deficiency points as discussed earlier (shown again in the left-half of Table 2-4 below for convenience). The new algorithm assigns deficiency points in an apparently similar manner but with three significant differences.

- The new algorithm includes the condition ratings for channel condition in addition to the ratings for deck, superstructure, and substructure.
- The 1991 algorithm assigned a maximum of 40 condition deficiency points while the new algorithm applies no such maximum.
- The 1991 algorithm did not multiply condition deficiency points by ADT or detour length factors, whereas the new algorithm does.

Table 2-4. Deficiency Points for Poor Condition Ratings

Condition Rating	- - - - - - 1991 Algorithm - - - - - -			Condition Rating	- - - - - - - New Algorithm - - - - - - -		
	Deck	Super-structure	Sub-structure		Lowest Rating*	2nd Lowest Rating*	3rd Lowest Rating*
4	5	10	15	4	20	10	5
3	10	20	30	<=3	30	20	10
<=2	20	40	60				

*of deck, superstructure, substructure and channel condition ratings for bridges, or of culvert and channel condition ratings for culverts

Table 2-5 compares the condition deficiency points assigned to state-owned bridges by the 1991 and the new algorithms. The new algorithm assigned condition deficiency points to slightly more bridges (148 vs. 123), but assigned considerably more deficiency points.

Table 2-5. Distribution of Bridges with Condition Deficiency Points: 1991 Algorithm vs. New Algorithm

Condition Deficiency Points	- - - - - - - Number of Bridges - - - - - -	
	1991 Algorithm	New Algorithm
5	16	0
10	40	0
15	52	0
20	5	3
25	4	92
30	3	25
35	0	11
40	3	10
45	0	3
50	0	1
55	0	0
60	0	3
Sum:	123	148

Width Deficiency Points

Based on experience using the 1991 algorithm as a tool for selecting bridges for replacement, narrow bridges were not assigned enough deficiency points. The possible deficiency points for narrow bridges were therefore increased from 10 to 20, and the width criteria were made more stringent. Width criteria from the two algorithms are compared in Table 2-6.

The 1991 deficiency algorithm project set "minimum" and "desirable" goals for all criteria, but only the "minimum" goals were used. The bridge width criteria for the new algorithm represent the "desirable" width goals from the 1991 project.

Table 2-6. Comparison of Bridge Width Criteria: 1991 Algorithm vs. New Algorithm

	1991 Algorithm	New Algorithm
Lane Width, ft	12	12
Shoulder Width, ft		
2-way traffic (both shoulders)	2	10
1-way traffic, right shoulder	2	10
1-way traffic, left shoulder	2	6

To calculate width deficiency points for a particular bridge, target widths are calculated. Calculation of target widths is illustrated below for a two-lane bridge carrying two-way traffic.

1991 algorithm: target_width = (12'/lane)(2 lanes) + 2' + 2' = 28'
New algorithm: target_width = (12'/lane)(2 lanes) + 10' + 10' = 44'

Bridges with widths greater than the above targets would be assigned no deficiency points. Width deficiency points are assigned to each bridge by comparing the curb-to-curb width of the actual bridge against the target widths, as illustrated in Figure 2-6 below. The width deficiency points are multiplied by the ADT and detour length factors to get the total width deficiency.

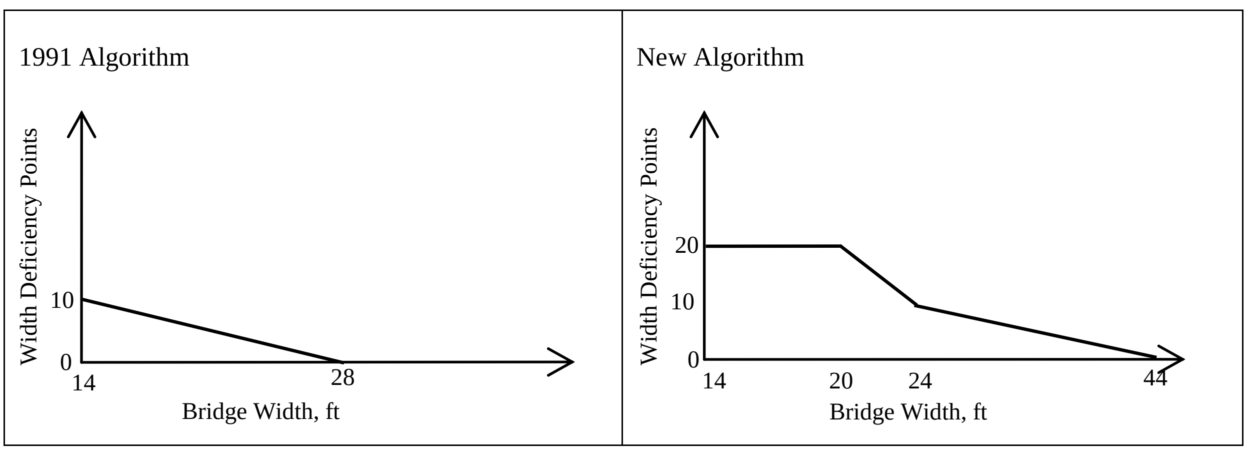


Figure 2-6. Example width deficiency point calculation for two-lane bridge: 1991 algorithm vs. new algorithm.

The example width deficiency functions shown in Figure 2-6 show that the new algorithm assigns more width deficiency points than the 1991 algorithm. Table 2-7 shows the distributions of width deficiency points assigned by the two algorithms for all state-owned bridges. The new algorithm assigns more width deficiency points due to the following three factors:

- 20 points possible vs. only 10 points possible for the 1991 algorithm
- more stringent criteria
- 1991 algorithm applied ADT and detour factors before enforcing maximum of 10 width deficiency points

Table 2-7. Distribution of Bridges with Width Deficiency Points: 1991 Algorithm vs. New Algorithm

Width Deficiency Points	- - - - - Number of Bridges - - - - -	
	1991 Algorithm	New Algorithm
2	447	563
4	12	419
6	38	121
8	101	121
10	476	764
12	0	471
14	0	166
16	0	24
18	0	37
20	0	22
22	0	14
24	0	27
26	0	5
28	0	3

Vertical Clearance Deficiency Points

Vertical clearance deficiency points are calculated similarly for both the 1991 and the new algorithms. Both algorithms assign up to 10 deficiency points. The new algorithm uses more stringent criteria. (See Figure 2-7.) And whereas the 1991 algorithm applied the ADT and detour length factors before enforcing the maximum vertical clearance deficiency of 10 points, the new algorithm does not enforce a maximum.

The vertical clearance deficiency points are multiplied by the appropriate ADTT factor (since this deficiency affects truck traffic only) and detour length factor to get the total vertical clearance deficiency. Clearance deficiencies for the route over the bridge used the ADT, percentage of trucks, and detour length for the “on-bridge” route; and clearance deficiencies for the route under the bridge used the ADT, percentage of trucks, and detour length for the "under-bridge" route. For the rare bridge that has both on-bridge and under-bridge vertical clearance restrictions, the deficiency points for each are added to get the total vertical clearance deficiency for the bridge.

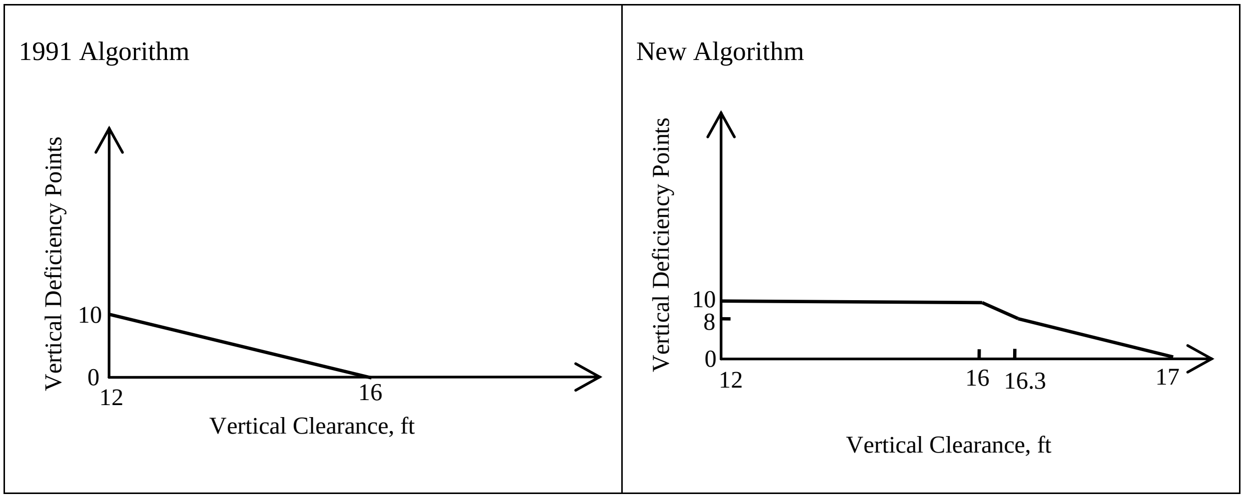


Figure 2-7. Vertical clearance deficiency point calculation: 1991 algorithm vs. new algorithm.

The vertical clearance deficiency functions shown in Figure 2-7 show that the new algorithm assigns more width deficiency points than the 1991 algorithm. Table 2-8 shows the distributions of vertical clearance deficiency points assigned by the two algorithms for all state-owned bridges. The new algorithm assigns more vertical clearance deficiency points due to the following two factors:

- more stringent criteria
- 1991 algorithm applied ADT and detour factors before enforcing maximum of 10 width deficiency points

Table 2-8. Distribution of Bridges with Vertical Clearance Deficiency Points: 1991 Algorithm vs. New Algorithm

Vertical Clearance Deficiency Points	- - - - - Number of Bridges - - - - -	
	1991 Algorithm	New Algorithm
2	4	60
4	6	80
6	4	60
8	2	69
10	54	86
12	0	108
14	0	28
16	0	2
18	0	2

ADT, ADTT, and Detour Length Factors

These factors serve as multipliers to increase deficiency points for bridges with relatively high ADT, ADTT, and/or detour length. The ADT factor for a bridge is based on the percent rank of the bridge ADT out of all bridges and culverts in Alabama. For example, the percent rank of an ADT = 1200 (the median ADT) is 0.50, and the percent rank of an ADT = 200,000 is 1.0.

The distributions of ADT, ADTT, and detour length are shown in Figures 2-8a, 2-9a, and 2-10a. The ADT factor, the ADTT factor, and the detour length factor are shown in Figures 2-8b, 2-9b, and 2-10b along with the factors from the 1991 algorithm for comparison. The following observations can be made:

- <u>ADT Factor</u> The ADT factor for the 1991 algorithm was unreasonable, nearly tripling the deficiency points for bridges with very high traffic volumes, and reducing to zero the deficiency points for bridges with very low traffic volumes. (See Figure 2-8a.) The ADT factor for the new algorithm increases the deficiency points up to 30% for bridges with traffic volumes above the median but does not decrease the deficiency points for bridges with traffic volumes below the median. This compromise recognizes the urgency of high traffic volume bridges with serious deficiencies, but keeps low traffic volume bridges with serious deficiencies from being "outranked" by high traffic volume bridges with less serious deficiencies.

- <u>ADTT Factor</u> The 1991 algorithm did not use an average daily truck traffic (ADTT) factor. This factor is more appropriate than the ADT factor for multiplying deficiencies applicable to truck traffic only, such as load capacity and vertical clearance. ADTT is calculated by multiplying two database items as follows: ADTT = ADT x %_Trucks. In the new algorithm, deficiency points are increased by up to 30% for bridges with ADTT above the median. (See Figure 2-9b.)

- <u>Detour Length Factor</u> The detour length factor for the 1991 algorithm was not reasonable, increasing by up to 70% the deficiency points for bridges with greater than the minimum detour length of one mile. (See Figure 2-10b.) The detour length factor for the new algorithm increases by up to 10%) the deficiency points for bridges with detour lengths greater than the median detour length (four miles).

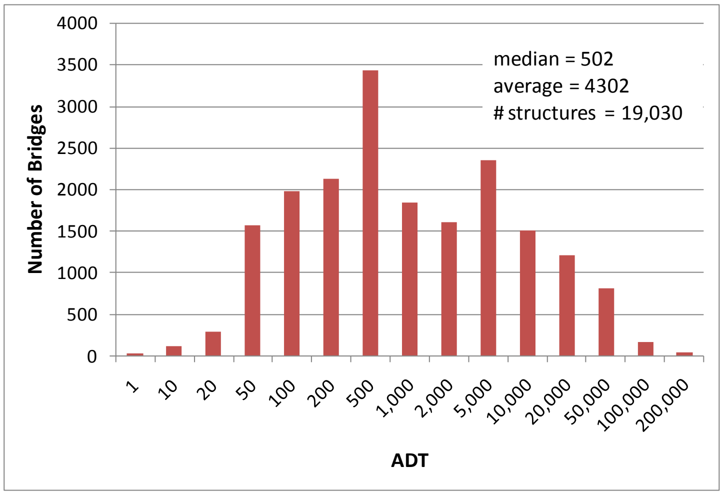


Figure 2-8a. Distribution of ADT on Alabama bridges and culverts.

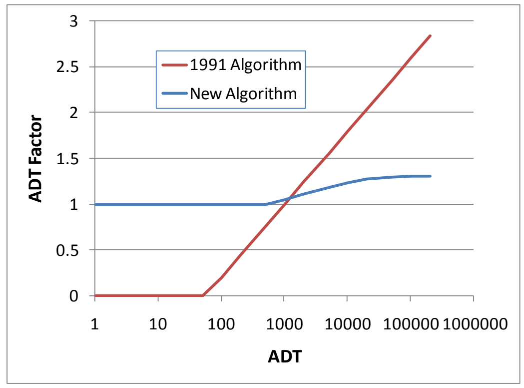


Figure 2-8b. ADT Factor: 1991 algorithm vs. new algorithm.

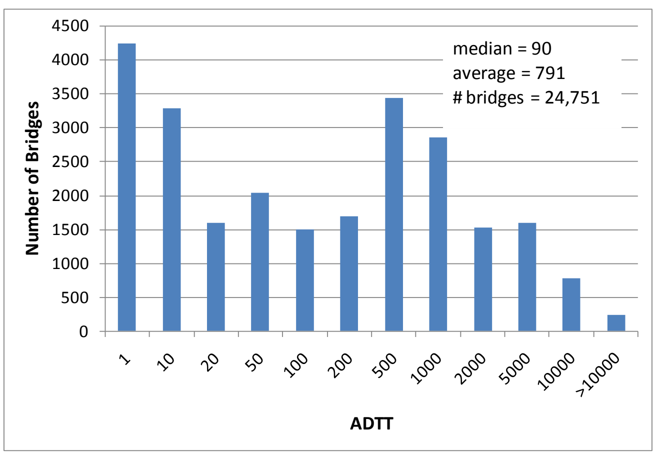


Figure 2-9a. Distribution of ADTT on Alabama bridges and culverts.

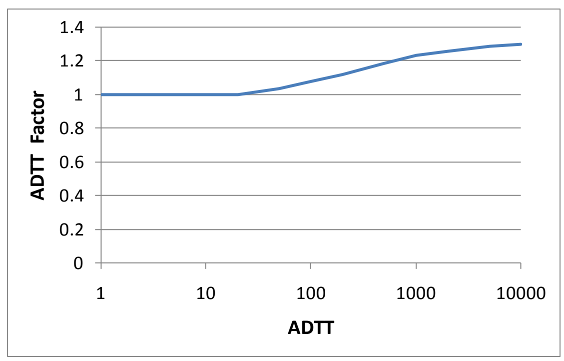


Figure 2-9b. ADTT factor for new algorithm.

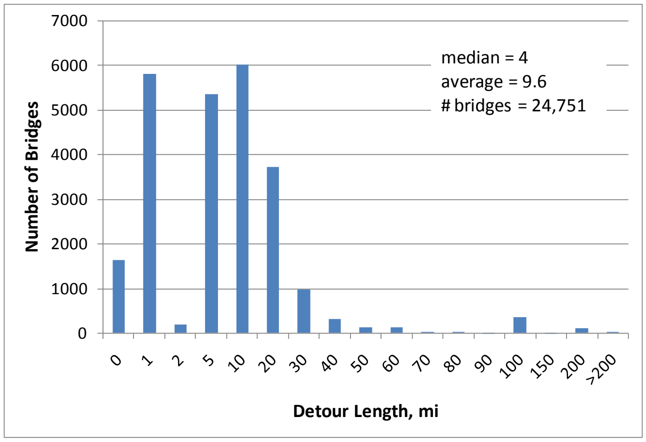


Figure 2-10a. Distribution of detour length on Alabama bridges and culverts.

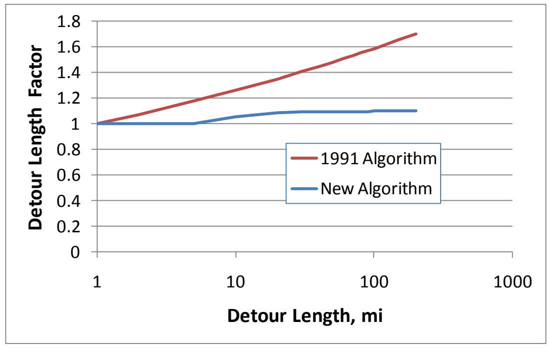


Figure 2-10b. Detour length factor: 1991 algorithm vs. new algorithm.

3.0 Evaluation of the New Algorithm

The performance of the new algorithm described in the previous section was assessed by comparing the ranked list of deficient bridges against three other lists:

- Bridges picked for replacement by bridge inspectors from Divisions 6 and 8
- Bridges on the Five-Year Bridge Replacement Program, FY 2007 – 2011
- Bridges ranked by the 1991 deficiency algorithm

Comparison with Division Bridge Inspectors

The new algorithm was used to produce a list of deficient bridges for a single ALDOT division. The project team traveled to the division and met individually with the division bridge inspector. During the meeting, the inspector commented on the list of deficient bridges and on the deficiency algorithm in general. A summary of those comments are presented below for Division 8 and Division 6.

For both divisions, most of the 20 most-deficient bridges were scheduled for replacement. Reasonable explanations were provided for almost all of the exceptions.

- Division 8 Bridges The most-deficient bridges for Division 8 are listed in Table 3-1. The first column of the table indicates the replacement status of the bridge, according to the bridge inspector. Of the 20 most-deficient bridges, 18 were either replaced (R) or scheduled to be replaced (S).

  No explanation was provided for bridge #2910 with rank 10 not being scheduled for replacement. Bridge #9625 with rank 18 is a relief bridge (over a flood plain, normally dry) over a dirt road with an underclearance of 10.4 feet. The bridge inspector commented that since the dirt road has virtually no traffic, the underclearance should possibly be removed from the database.

  Bridge #2319 rank 34 was scheduled for replacement because it is of similar type and near Bridge #2320 rank 7 which is scheduled for replacement. Bridge #2670 rank 104 is a culvert scheduled for replacement as part of a road widening project. The culvert was built in 1942 and although it is in good condition, it makes more sense to replace the entire culvert rather than add a new section to lengthen it.

  Note that the two bridges already replaced have a posting status of "K" (closed). The bridge inspector recommended that the deficiency algorithm list the closed bridges as deficient (based on condition, width and vertical clearance) but not move the bridge to the top of the list.

- Division 6 Bridges The most-deficient bridges for Division 6 are listed in Table 3-2. Of the 21 most-deficient bridges, eight were scheduled to be replaced (S). Comments on the 13 of these 21 bridges not scheduled to be replaced are summarized below:

Rank	Bin	Comment
2	19618	has been strengthened by adding false bents
4	2853	no comment
7	1911	channel condition = 4, but Sufficiency Rating = 62 (not eligible)
10	1695	channel condition = 4, but Sufficiency Rating = 62
11	271	on historic route (Selma to Montgomery civil rights march)
12	11726	division ranking = 121
13	10690	has fatigue-prone pin and hanger connection, but Suf. Rating = 61
15	8803	channel cond. = 4, plan to encase piles in concrete and riprap channel
16	5088	no comment
17	12988	channel cond. = 4, will be fixed by district
20	9542	underclearance needs to be remeasured (likely error in database)
25	9528	underclearance needs to be remeasured (likely error in database)
78	3041	will be replaced as part of route realignment
79	3042	will be replaced as part of route realignment
125	1031	on same route and similar to BIN 1029 (rank 14)

Table 3-1. Division 8 Bridges Scheduled to be Replaced (S) or Already Replaced (R)

Replacement Status	Rank	Bin	Div	Facil_Carried	Features_Intersected	Sufficiency_Rating	Posting_Status	Op_Rating	H_Truck	2_AXLE_TRUCK	TRIAXLE_DUMP	CONCRETE_Truck	18_WHEELER	6_AXLE	SCHOOL_BUS	Deck_Cond	Super_Struc_Cond	Sub_Struc_Cond	Culvert_Cond	Channel_Cond	Width_on	Num_lanes_on	Direction_of_Traffic	OverClearance	UnderClearance	Load_Defic	Cond_Defic	Width_Defic	Vert_Clear_Defic	**Total_Defic**
S	1	3817	8	S.R. 69	JACKSON CREEK	6	A	10								5	5	4	N	5	22	2	2-way	99.99	0	0.0	23.4	18.5	0.0	41.9
S	2	3818	8	S.R. 69	JACKSON CREEK RELIEF	6	A	10								5	5	4	N	6	22	2	2-way	99.99	0	0.0	23.4	18.5	0.0	41.9
S	3	1268	8	S.R.69	KANETUCHE CREEK	43	A	50								5	5	4	N	5	22	2	2-way	99.99	0	0.0	23.0	18.1	0.0	41.1
R	4	1739	8	U.S.43	BATES CRK.	6	K	10	37	53	49	48	82	80	43	5	5	4	N	5	24	2	1-way	99.99	0	0.0	25.6	14.1	0.0	39.7
S	5	1917	8	U.S.43	LEWIS CRK.	6	A	10	26	53	49	48	82	82	43	5	5	4	N	5	24	2	1-way	99.99	0	0.0	25.5	14.0	0.0	39.5
R	6	1918	8	U.S.43	ROBERTS CREEK	6	K									5	5	4	N	6	24	2	1-way	99.99	0	0.0	25.5	14.0	0.0	39.5
S	7	2320	8	US. 45 & S.R. 17	CREEK	44	D	62								5	6	4	N	5	24	2	2-way	99.99	0	0.0	25.1	12.5	0.0	37.6
S	8	5977	8	S.R. 69	BRANCH	6	D	3								5	5	4	N	6	24	2	2-way	99.99	0	0.0	23.9	13.2	0.0	37.1
S	9	3016	8	U.S.80	FRENCH CRK.	33	A	49								6	5	4	N	5	26	2	1-way	99.99	0	0.0	25.8	11.4	0.0	37.1
	10	2910	8	U.S. 11	YELLOW CREEK	38	A	56								5	4	5	N	6	26	2	2-way	99.99	0	0.0	25.5	11.6	0.0	37.1
S	11	4797	8	U.S.80	SUCARNOOCHEE CRK.REL.	6	K									5	6	4	N	7	28	2	2-way	99.99	0	0.0	26.0	10.6	0.0	36.6
S	12	1717	8	S.R.5	MUD CRK.	50	A	65								5	5	4	N	5	24	2	2-way	99.99	0	0.0	23.4	12.9	0.0	36.3
S	13	3033	8	U.S.84	ESCAMBIA CREEK	44	A	55								5	4	5	N	6	26	2	2-way	99.99	0	0.0	24.8	11.4	0.0	36.2
S	14	2566	8	S.R.28	RELIEF	6	A	10	10	10	10	10	10	10	10	5	6	4	N	5	24	2	2-way	99.99	0	0.0	23.3	12.8	0.0	36.0
S	15	2567	8	S.R.28	CHICKASAW BOGUE CRK.	6	A	10	31	43	46	44	55	78	40	5	5	4	N	5	24	2	2-way	99.99	0	0.0	23.3	12.8	0.0	36.0
S	16	843	8	S.R.156	BRANCH	49	A	70								5	5	4	N	6	24	2	2-way	99.99	0	0.0	22.9	11.4	0.0	34.3
S	17	3024	8	S.R.10	SPEARS CRK.	12	D	10	28	34	38	33	54	55	34	5	5	4	N	5	26	2	2-way	99.99	0	0.0	21.8	10.1	0.0	31.9
	18	9625	8	S.R.10	COUNTY ROAD	63	A	53	40	49	47	46	78	78	48	6	6	6	N	9	28	2	2-way	99.99	10.4	0.0	0.0	10.2	13.2	23.4
S	19	6201	8	U.S. 84	TOMBIGBEE RIVER	44	A	34								5	5	5	N	5	26	2	2-way	16.17	0.00	0.0	0.0	11.1	11.6	22.7
S	20	4794	8	US 80	S.R.17	51	A	53								5	5	6	N	N	28	2	2-way	99.99	16.07	0.0	0.0	10.3	9.5	19.8
	21	3300	8	S.R.69	SALITPA CRK.REL.	72	A	51	32	43	38	38	63	60	39	6	6	6	N	5	22	2	2-way	99.99	0	0.0	0.0	18.1	0.0	18.1
	22	3301	8	S.R.69	SALITPA CRK.	71	A	49								6	6	6	N	5	22	2	2-way	99.99	0	0.0	0.0	18.1	0.0	18.1
	23	3302	8	S.R.69	EBERLEIN MILL CRK.	63	A	53								6	5	6	N	5	22	2	2-way	99.99	0	0.0	0.0	17.7	0.0	17.7
	24	2547	8	U.S.43	FRISCO R.R. OVERPASS	44	A	47								6	5	5	N	N	24	2	2-way	99.99	21.75	0.0	0.0	14.3	0.0	14.3
	25	1762	8	S.R.21	FRISCO R.R.	55	A	48								5	5	6	N	N	24	2	2-way	99.99	22.01	0.0	0.0	13.4	0.0	13.4
	26	2261	8	S.R.5	CUB CREEK	63	A	73	52	46	49	47	60	62	43	5	5	5	N	5	24	2	2-way	99.99	0	0.0	0.0	13.3	0.0	13.3
	27	2262	8	S.R.5	MOCCASIN CREEK	63	A	66								5	5	5	N	6	24	2	2-way	99.99	0	0.0	0.0	13.3	0.0	13.3
	28	5206	8	S.R.28	BARTON CRK.	56	A	45								5	5	5	N	5	24	2	2-way	99.99	0	0.0	0.0	12.8	0.0	12.8
	29	2555	8	S.R.17	SOUWILPA CREEK	79	A	61								6	6	6	N	6	24	2	2-way	99.99	0	0.0	0.0	12.7	0.0	12.7
	30	5205	8	S.R.28	DOUBLE CRK.	61	A	50								5	5	5	N	6	24	2	2-way	99.99	0	0.0	0.0	12.6	0.0	12.6
S	34	2319	8	US. 45 & S.R. 17	BRANCH	57	D	50								5	5	5	N	5	24	2	2-way	99.99	0	0.0	0.0	12.5	0.0	12.5
S	104	2670	8	U.S.43	SPRINGFIELD CRK.	66	A	62	30	43	51	42	59	66	27	N	N	N	6	6	29	2	2-way	99.99	0	0.0	0.0	10.2	0.0	10.2

Table 3-2. Division 6 Bridges Scheduled to be Replaced (S)

Replacement Status	Rank	Bin	Div	Facil_Carried	Features_Intersected	Sufficiency_Rating	Posting_Status	Op_Rating	H_Truck	2_AXLE_TRUCK	TRIAXLE_DUMP	CONCRETE_Truck	18_WHEELER	6_AXLE	SCHOOL_BUS	Deck_Cond	Super_Struc_Cond	Sub_Struc_Cond	Culvert_Cond	Channel_Cond	Width_on	Num_lanes_on	Direction_of_Traffic	OverClearance	UnderClearance	Load_Defic	Cond_Defic	Width_Defic	Vert_Clear_Defic	**Total_Defic**
S	1	2736	6	AL 206	AUTAUGA CREEK	7	P	15	15	15	15	15	15	15	15	6	5	2	N	5	26	2	2-way	99.99	0	57.2	36.4	11.0	0.0	104.6
	2	19818	6	AL0601 (OLD AL143	CSX RAIL ROAD	29	D	40	25	37	40	36	51	53	29	3	3	3	N	N	24	2	2-way	99.99	22	0.0	60.0	10.3	0.0	70.3
S	3	885	6	US 80 WBL	OLD TOWN CREEK	13	D	10								5	4	4	N	6	24	2	1-way	99.99	0	0.0	32.7	10.9	0.0	43.5
S	4	2550	6	AL 14	TALLAPOOSA RIVER	6	D	13								5	4	5	N	7	26	2	2-way	99.99	0	0.0	27.3	12.4	0.0	39.7
	5	1911	6	US 82	SWIFT CREEK	62	A	66								5	5	5	N	4	24	2	2-way	99.99	0	0.0	24.7	13.3	0.0	38.0
S	6	2273	6	US 80	ALABAMA RIVER	43	A	34								6	5	6	N	7	42	4	2-way	15.32	0	0.0	0.0	21.8	14.9	36.7
S	7	2913	6	US 80 W.B.L.	MUD CREEK RELIEF	32	A	46	33	42	40	39	65	64	41	6	4	6	N	6	26	2	1-way	99.99	0	0.0	24.7	10.9	0.0	35.6
	8	1695	6	AL.10	PERSIMMON CREEK	62	D	57								5	5	5	N	4	24	2	2-way	99.99	0.00	0.0	23.6	11.8	0.0	35.4
	9	271	6	US 80 WBL	TALLAWASSEE CREEK	12	D	10								5	4	0	N	5	24	2	1-way	99.99	0	0.0	21.8	10.9	0.0	32.8
	10	11726	6	AL. 10	STALLINGS CREEK	48	A	61								6	4	5	N	6	52	4	2-way	99.99	0	0.0	23.0	9.3	0.0	32.3
	11	10690	6	I65 RAMP 52	W.JEFF DAVIS AVE	61	D	48								7	4	6	N	N	26	1	1-way	99.99	16.27	0.0	22.3	1.5	8.2	32.0
S	12	1029	6	US 80 WBL	BOGUE CHITTO CRK	16	D	10								5	5	4	N	6	24	2	1-way	99.99	0	0.0	20.7	10.4	0.0	31.1
	13	8803	6	US 231NBL	SANDY CREEK	65	A	74								6	6	5	N	4	28	2	1-way	99.99	0	0.0	22.6	8.5	0.0	31.1
	14	5088	6	US 31 NBL	CATOMA CREEK	65	A	65								4	5	6	N	6	28	2	1-way	99.99	0	0.0	22.3	8.4	0.0	30.7
S	15	4947	6	AL. 106	PIGEON CREEK	49	P	25	27	30	32	32	52	50	33	6	6	6	N	5	22	2	2-way	99.99	0	10.8	0.0	17.9	0.0	28.7
	16	12988	6	AL14	WALLAHATCHEE CREEK#2	79	A	74	40	65	60	60	74	75	64	7	7	5	N	4	40	2	2-way	99.99	0.00	0.0	25.4	2.5	0.0	28.0
	17	17757	6	US 80 WBL & EBL	CANEY CREEK	64	A	99								N	N	N	6	7	24	4	2-way	99.99	0	0.0	0.0	27.8	0.0	27.8
	18	7561	6	CO 64	I85	43	A	56								6	5	7	N	N	24	2	2-way	99.99	16.1	0.0	0.0	12.3	11.8	24.1
	19	9542	6	HALL ST	I85	79	A	48								6	6	7	N	N	52	4	2-way	99.99	15.78	0.0	0.0	9.9	13.1	22.9
S	20	928	6	AL.212	COOSA RIVER	42	A	25								6	5	6	N	7	27	2	2-way	12.5	0	0.0	0.0	10.2	12.0	22.2
	21	6782	6	CO RD 15	I65	68	A	56								7	7	7	N	N	24	2	2-way	99.99	16.17	0.0	0.0	11.2	11.0	22.2
	22	8557	6	CO 40	I65	65	A	98								7	5	7	N	N	24	2	2-way	99.99	16.14	0.0	0.0	10.4	11.6	22.0
	23	6783	6	CO RD 16	I65	59	A	56								7	5	7	N	N	24	2	2-way	99.99	16.24	0.0	0.0	11.0	10.4	21.4
	24	2853	6	AL. 81	UPHAPEE CREEK	49	P	33	20	30	28	28	40	42	13	6	5	5	N	6	26	2	2-way	99.99	0	10.6	0.0	10.5	0.0	21.1
	25	9528	6	CITY ST	I65	87	A	48								7	6	7	N	N	28	2	2-way	99.99	15.74	0.0	0.0	8.1	12.8	20.9
	26	9527	6	I65 NBL	CO 45	72	A	58	44	55	51	51	67	67	55	7	6	7	N	N	28	2	1-way	99.99	15.81	0.0	0.0	8.7	11.7	20.4
	27	18421	6	I65	AL RIVER RELIEF NO.11	70	A	49	40	62	61	51	70	79	50	7	7	7	N	8	21	2	1-way	99.99	0	0.0	0.0	20.2	0.0	20.2
	28	9286	6	FORREST AVE.	IN 85	92	A	48								7	7	7	N	N	70	5	2-way	99.99	16.04	0.0	0.0	5.8	13.0	18.7
	29	9780	6	BELL STREET	I-65 AND RAMPS I AND J	73	A	48								6	6	7	N	N	52	4	2-way	99.99	16.33	0.0	0.0	9.6	9.1	18.7
	30	8559	6	CO 59	I65	81	A	87								7	7	7	N	N	25	2	2-way	99.99	16.43	0.0	0.0	10.3	8.3	18.6
	31	9543	6	PERRY HILL RD(SBL)	I85	80	A	58								6	6	7	N	N	30	2	1-way	99.99	15.9	0.0	0.0	7.1	11.3	18.4
	32	9544	6	PERRY HILL RD(NBL)	I85	80	A	58								6	6	7	N	N	30	2	1-way	99.99	15.9	0.0	0.0	7.1	11.3	18.4
	33	9003	6	LAWRENCE ST	I85	76	A	73								7	7	7	N	N	44	4	1-way	99.99	16.83	0.0	0.0	16.0	2.4	18.4
	34	4716	6	AL 22	VALLEY CREEK	51	A	25								6	7	6	N	6	44	4	2-way	99.99	0	0.0	0.0	17.9	0.0	17.9
S	78	3041	6	AL.14	IVY CREEK	47	A	45	34	44	40	40	66	63	41	6	6	5	N	7	26	2	2-way	99.99	0	0.0	0.0	11.6	0.0	11.6
S	79	3042	6	AL.14	BEAVER CREEK	49	A	46	34	45	41	41	67	65	42	6	5	5	N	6	26	2	2-way	99.99	0	0.0	0.0	11.6	0.0	11.6
S	125	1031	6	US 80 WBL	CHANEY CRK	21	D	10								6	7	5	N	7	24	2	1-way	99.99	0	0.0	0.0	10.3	0.0	10.3

Comparison with the Five-Year Bridge Replacement Program

ALDOT managers selected 191 bridges to be replaced over a five-year period (2007 – 2011). The distribution of the deficiency rankings of these 191 bridges is shown in Figures 3-1 and 3-2. Of the 191 bridges, 181 were included in the 1700 most-deficient bridges. The other 10 bridges had no deficiency points assigned. Figure 3-2 shows that of the 50 most-deficient bridges, all but nine were selected to be replaced.

Overall, the deficiency algorithm performed satisfactorily, considering many bridges are selected for the replacement program based on information not available in the bridge database.

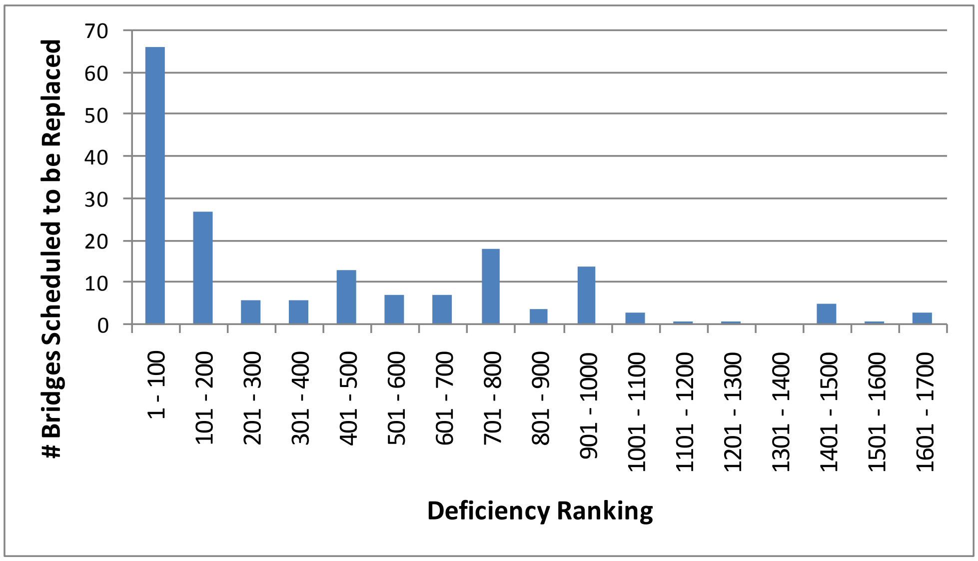


Figure 3-1. 182 of 191 bridges in five-year bridge replacement program in 1700 most-deficient bridges.

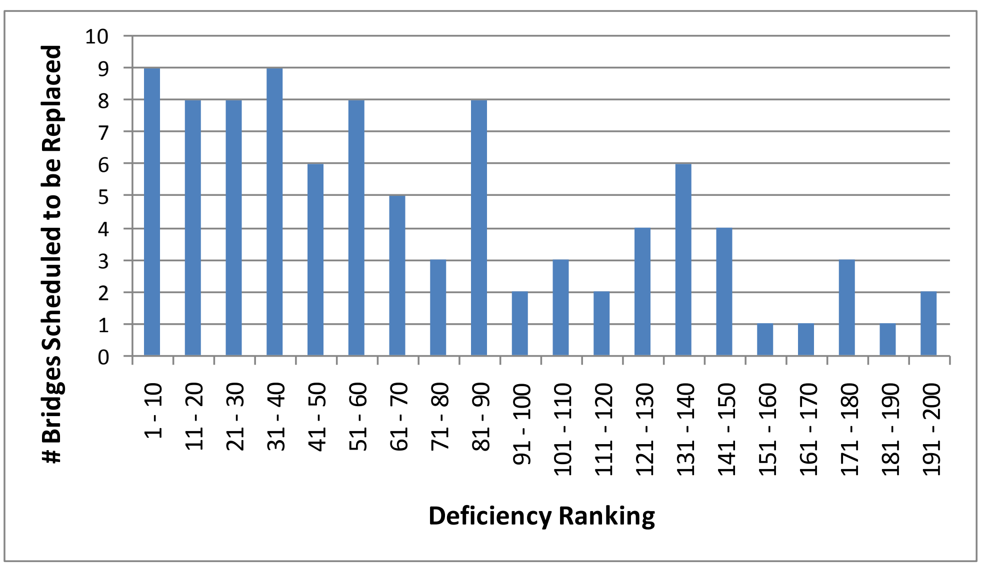


Figure 3-2. 93 of 191 bridges in five-year bridge replacement program in 200 most-deficient bridges.

Comparison with the 1991 Deficiency Algorithm

The 100 most-deficient bridges according to the new algorithm were compared bridge-by-bridge with the deficiency ranks calculated by the 1991 algorithm. Tables 3-3 and 3-4 present the individual bridge data.

The major cause for the difference in rankings between the two algorithms is the 1991 algorithm over-assigned load deficiency points and under-assigned condition deficiency points. The 1991 algorithm assigned load deficiency points to 834 bridges compared with only 9 for the new algorithm. (See Table 2-3.) And although the two algorithms assigned condition deficiency points to approximately the same number of bridges, the new algorithm assigned approximately three times as many condition deficiency points.

Every one of the bridges in Tables 3-3 and 3-4 with a 1991 ranking greater than 500 had zero load deficiency points from the 1991 algorithm. These bridges are listed below with a comment regarding the cause of the discrepancy. The major cause was under-assignment of condition deficiency points.

New Rank	1991 Rank	1991 Algorithm
11	2905	assigned no deficiency points (error?)
25	662	assigned no deficiency points for channel condition = 4
30	567	assigned no deficiency points for channel condition = 4
32	686	only assigns 5 deficiency points for deck condition = 4
35	536	assigned no deficiency points for channel condition = 4
40	1446	did not evaluate culverts
49	2882	assigned no deficiency points?
51	539	assigned only 15 deficiency points for substructure condition = 4
54	831	assigned no deficiency points for channel condition = 4, no width points
56	1103	assigned only 5 deficiency points for deck condition = 4, no width points
58	540	assigned only 15 deficiency points for substructure condition = 4
60	542	assigned only 15 deficiency points for substructure condition = 4
65	759	assigned only 10 points for superstructure condition = 4, no width points
72	537	assigned only 15 deficiency points for substructure condition = 4
73	541	assigned only 15 deficiency points for substructure condition = 4
74	790	assigned no deficiency points for channel condition = 4
79	656	assigned only 10 points for superstructure condition = 4
81	660	assigned only 10 points for superstructure condition = 4
86	1182	assigned no deficiency points for channel condition = 4
87	815	assigned no deficiency points for channel condition = 4
91	931	assigned only 10 points for narrow deck, no vert. clearance points
92	932	assigned only 10 points for narrow deck, no vert. clearance points

Table 3-3. Deficiency Points: 1991 Algorithm vs. New Algorithm Bridges Ranked 1 – 50

Bin	Posting_Status	Op_Rating	Inv_Rating	Deck_Cond	Super_Struc_Cond	Sub_Struc_Cond	Culvert_Cond	Channel_Cond	1991_Algo_Load_Defic_Pts	1991_Algo_Cond_Defic_Pts	1991_Algo_Width_Defic_Pts	1991_Algo_Vert_Defic_Pts	1991_Algo_Special_Points	1991_Algo_Total_Defic_Pts	1991_Algo_Rank		Load_Defic	Cond_Defic	Width_Defic	Vert_Clear_Defic	**Total_Defic**	Rank
1841	P	3	2	3	3	5	N	5	40	30	0	0	40	100	3		57.2	55.9	8.2	0.0	121.4	1
529	P	15	11	4	5	4	N	N	40	20	10	0	40	100	1		57.2	34.3	22.9	0.0	114.4	2
635	P	3	2	5	5	3	N	7	40	30	1.1	0	40	100	2		57.2	38.0	10.3	0.0	105.6	3
2736	P	15	11	6	5	2	N	5	40	40	8.4	0	40	100	4		57.2	36.4	11.0	0.0	104.6	4
1842	P	6	4	4	7	5	N	4	40	5	0	0	40	85	18		57.2	34.1	7.3	0.0	98.5	5
504	P	6.1	4	5	5	4	N	7	40	15	1	0	40	96	6		57.2	24.8	10.1	0.0	92.1	6
7608	P	13	10	7	7	4	N	N	40	15	0	0	0	55	80		57.2	22.3	9.0	0.0	88.5	7
2037	P	6.9	4.1	6	4	5	N	7	40	10	0	0	40	90	9		57.2	24.1	5.4	0.0	86.7	8
1765	P	6.1	4	5	7	4	N	7	40	15	0.7	0	40	95.7	7		42.3	24.8	10.1	0.0	77.2	9
4507	D	15	10	4	3	4	N	7	40	40	10	0	0	90	11		0.0	58.3	13.0	0.0	71.3	10
19818	D	39.7	36	3	3	3	N	N	0	0	0	0	0	0	2905		0.0	60.0	10.3	0.0	70.3	11
503	D	3	2	4	3	6	N	7	40	25	10	0	0	75	24		0.0	43.6	21.8	0.0	65.4	12
1394	D		0	3	5	6	N	5	40	10	10	0	0	60	57		0.0	37.1	24.7	0.0	61.8	13
1798	D	10	7.5	4	5	4	N	3	40	20	6.9	0	0	66.9	30		0.0	49.7	11.0	0.0	60.7	14
784	E	10	7.5	5	4	5	N	6	40	10	10	10	0	70	26		0.0	22.4	22.4	12.2	57.0	15
474	D	10	7.5	6	6	4	N	4	40	15	7.7	0	0	62.7	53		0.0	31.0	20.6	0.0	51.6	16
615	D	10	7.5	4	6	5	N	5	40	5	10	0	0	55	77		0.0	25.1	25.1	0.0	50.3	17
2712	A	6	4	4	6	4	N	5	40	20	10	0	0	70	28		0.0	37.2	12.4	0.0	49.5	18
6588	A	24	18	4	4	6	N	7	40	15	0.4	0	0	55.4	75		0.0	39.2	9.9	0.0	49.1	19
10132	D	10	7.5	5	4	4	N	4	40	25	0	0	0	65	48		0.0	40.8	8.2	0.0	49.1	20
10102	A	35.9	21.5	4	4	5	N	5	40	15	0	0	0	55	82		0.0	38.7	10.3	0.0	49.0	21
7365	A	24	18	4	4	6	N	7	40	15	0.4	0	0	55.4	76		0.0	39.1	9.8	0.0	48.9	22
9367	D	10	7	4	4	4	N	N	40	30	0	0	30	100	5		0.0	41.1	7.1	0.0	48.2	23
5816	D	10	7	4	4	7	N	6	40	15	0.9	0	0	55.9	71		0.0	37.6	10.2	0.0	47.8	24
12793	A	47.9	36	7	7	4	N	4	0	15	1.7	0	0	16.7	662		0.0	36.7	10.0	0.0	46.7	25
502	A	50.1	30	4	4	6	N	7	20.3	15	10	0	0	45.3	195		0.0	32.6	13.6	0.0	46.1	26
770	A	56.9	35	4	5	5	N	N	0	5	10	0	30	45	200		0.0	23.1	23.1	0.0	46.1	27
1665	D	10	7.5	4	5	4	N	7	40	20	8.3	0	0	68.3	29		0.0	34.0	11.3	0.0	45.4	28
4658	A	51.9	28.9	5	5	4	N	4	29.5	15	7.8	0	0	52.3	87		0.0	34.4	10.3	0.0	44.7	29
1072	A	65.9	45.9	5	5	4	N	4	0	15	7	0	0	22	567		0.0	33.3	11.1	0.0	44.4	30
1368	A	40.9	24.5	4	5	4	N	6	40	20	10	0	0	70	27		0.0	32.7	11.7	0.0	44.4	31
798	A	59.4	36.9	4	5	5	N	5	0	5	10	0	0	15	686		0.0	22.1	22.1	0.0	44.2	32
4994	A	25	18.9	5	5	4	N	4	40	15	0	0	0	55	78		0.0	36.2	8.0	0.0	44.2	33
885	D	10	7.5	5	4	4	N	6	40	25	10	0	0	75	25		0.0	32.7	10.9	0.0	43.5	34
6473	A	48	36	5	4	4	N	6	0	25	0.4	0	0	25.4	536		0.0	34.2	8.6	0.0	42.9	35
3202	P	40.7	24.4	5	4	6	N	N	40	10	8.4	0	30	88.4	16		10.0	22.1	10.0	0.0	42.1	36
3817	A	10	7	5	5	4	N	5	40	15	10	0	0	65	44		0.0	23.4	18.5	0.0	41.9	37
3818	A	10	7	5	5	4	N	6	40	15	10	0	0	65	45		0.0	23.4	18.5	0.0	41.9	38
2627	D	10	7.5	5	5	4	N	4	40	15	10	0	0	65	42		0.0	30.9	10.3	0.0	41.2	39
617	D	10	7.5	N	N	N	4	5	0	0	0	0	0	0	1446		0.0	21.9	19.2	0.0	41.1	40
1268	A	49.9	29.9	5	5	4	N	5	23.8	15	10	0	0	48.8	144		0.0	23.0	18.1	0.0	41.1	41
3130	A	10	7	4	4	5	N	6	40	15	8.3	0	0	63.3	51		0.0	30.0	10.0	0.0	40.0	42
2844	P	27.2	16.1	6	7	6	N	5	40	0	0	0	40	80	20		31.7	0.0	8.2	0.0	39.8	43
2550	D	13	10	5	4	5	N	7	40	10	9.3	0	0	59.3	66		0.0	27.3	12.4	0.0	39.7	44
1739	K	10	7	5	5	4	N	5	40	15	10	0	0	65	37		0.0	25.6	14.1	0.0	39.7	45
1917	A	10	7	5	5	4	N	5	40	15	10	0	0	65	38		0.0	25.5	14.0	0.0	39.5	46
1918	K		0	5	5	4	N	6	40	15	10	0	0	65	39		0.0	25.5	14.0	0.0	39.5	47
10493	A	47.9	36	6	4	6	N	N	0	10	0	0	0	10	937		0.0	22.1	5.5	11.8	39.3	48
18614	K		0	5	6	2	N	7	0	0	0	0	0	0	2882		0.0	30.0	9.3	0.0	39.3	49
1897	A	46.9	29.9	6	5	4	N	5	31.8	15	10	0	0	56.8	69		0.0	26.1	13.0	0.0	39.1	50

Table 3-4. Deficiency Points: 1991 Algorithm vs. New Algorithm Bridges Ranked 51 – 100

Bin	Posting_Status	Op_Rating	Inv_Rating	Deck_Cond	Super_Struc_Cond	Sub_Struc_Cond	Culvert_Cond	Channel_Cond	1991_Algo_Load_Defic_Pts	1991_Algo_Cond_Defic_Pts	1991_Algo_Width_Defic_Pts	1991_Algo_Vert_Defic_Pts	1991_Algo_Special_Points	1991_Algo_Total_Defic_Pts	1991_Algo_Rank	Load_Defic	Cond_Defic	Width_Defic	Vert_Clear_Defic	**Total_Defic**	Rank
1898	A	52.9	36	6	6	4	N	5	0	15	10	0	0	25	539	0.0	26.1	13.0	0.0	39.1	51
1664	D	10	7.5	5	4	6	N	N	40	10	10	0	0	60	59	0.0	25.5	12.7	0.0	38.2	52
1613	D	10	7	5	4	5	N	6	40	10	10	0	0	60	58	0.0	25.5	12.7	0.0	38.2	53
1911	A	65.9	43.9	5	5	5	N	4	0	0	10	0	0	10	831	0.0	24.7	13.3	0.0	38.0	54
8648	D	24	18	6	4	6	N	7	40	10	10	0	0	60	64	0.0	22.9	15.1	0.0	38.0	55
7627	D	48	36	4	5	6	N	6	0	5	0.4	0	0	5.4	1103	0.0	27.4	10.4	0.0	37.8	56
5222	D	45.5	27.3	6	4	5	N	7	39.4	10	10	0	0	59.4	65	0.0	25.2	12.6	0.0	37.8	57
2013	D	97.8	97.8	5	5	4	N	5	0	15	10	0	0	25	540	0.0	25.1	12.5	0.0	37.6	58
1442	D	10	7.5	5	5	4	N	5	40	15	10	0	0	65	36	0.0	25.1	12.5	0.0	37.6	59
2320	D	61.8	40.9	5	6	4	N	5	0	15	10	0	0	25	542	0.0	25.1	12.5	0.0	37.6	60
5430	D	24	18	5	4	5	N	5	40	10	10	0	0	60	63	0.0	22.9	14.5	0.0	37.4	61
2408	D	10	7.5	5	4	5	N	8	40	10	10	0	0	60	62	0.0	24.8	12.4	0.0	37.2	62
5977	D	3	2	5	5	4	N	6	40	15	10	0	0	65	46	0.0	23.9	13.2	0.0	37.1	63
3016	A	49	27.9	6	5	4	N	5	40	15	8	0	0	63	52	0.0	25.8	11.4	0.0	37.1	64
2910	A	55.9	38	5	4	5	N	6	0	10	0.4	0	0	10.4	759	0.0	25.5	11.6	0.0	37.1	65
2866	D	3	2	4	5	5	N	7	40	5	9.2	0	0	54.2	85	0.0	25.5	11.5	0.0	36.9	66
476	A	10	7.5	5	4	6	N	5	40	10	10	0	0	60	55	0.0	23.2	13.7	0.0	36.9	67
2588	A	19.9	15	6	5	5	N	4	40	0	10	0	0	50	109	0.0	24.5	12.3	0.0	36.8	68
2273	A	33.9	25	6	5	6	N	7	40	0	10	0	0	50	106	0.0	0.0	21.8	14.9	36.7	69
4797	K		0	5	6	4	N	7	40	15	1.2	0	0	56.2	70	0.0	26.0	10.6	0.0	36.6	70
6434	D	37.7	22.6	5	4	5	N	6	40	10	1.2	0	0	51.2	88	0.0	25.9	10.6	0.0	36.5	71
1717	A	64.9	43.9	5	5	4	N	5	0	15	10	0	0	25	537	0.0	23.4	12.9	0.0	36.3	72
2253	A	61.8	41.9	7	7	4	N	6	0	15	10	0	0	25	541	0.0	24.2	12.1	0.0	36.3	73
486	A	63.9	40.9	6	7	6	N	4	0	0	10	0	0	10	790	0.0	22.8	13.4	0.0	36.2	74
4202	A	17	11	4	5	5	N	6	40	5	0.4	0	0	45.4	193	0.0	25.8	10.4	0.0	36.2	75
3033	A	54.9	33.9	5	4	5	N	6	12.4	10	9.6	0	0	31.9	445	0.0	24.8	11.4	0.0	36.2	76
2566	A	10	7	5	6	4	N	5	40	15	10	0	0	65	40	0.0	23.3	12.8	0.0	36.0	77
2567	A	10	7	5	5	4	N	5	40	15	10	0	0	65	41	0.0	23.3	12.8	0.0	36.0	78
8466	A	49.9	29.9	6	4	7	N	7	0	10	7	0	0	17	656	0.0	24.0	12.0	0.0	36.0	79
14407	D	24	18	5	4	6	N	N	40	10	0	0	0	50	130	0.0	23.9	0.0	11.9	35.8	80
8467	A	49.9	29.9	6	4	7	N	6	0	10	6.8	0	0	16.8	660	0.0	23.8	11.9	0.0	35.7	81
2913	A	45.5	27.3	6	4	6	N	6	37.4	10	7.3	0	0	54.6	84	0.0	24.7	10.9	0.0	35.6	82
1273	D	10	7	5	6	4	N	6	40	15	10	0	0	65	32	0.0	23.7	11.8	0.0	35.5	83
1274	D	10	7	5	5	4	N	6	40	15	10	0	0	65	33	0.0	23.7	11.8	0.0	35.5	84
1276	D	10	7	5	5	4	N	7	40	15	10	0	0	65	35	0.0	23.7	11.8	0.0	35.5	85
10083	P	38.9	27	7	6	5	N	4	0	0	1.5	0	0	1.5	1182	0.0	20.0	15.5	0.0	35.5	86
1695	D	56.9	40.9	5	5	5	N	4	0	0	10	0	0	10	815	0.0	23.6	11.8	0.0	35.4	87
7029	D	24	18	5	4	5	N	7	40	10	0	0	0	50	123	0.0	25.2	10.1	0.0	35.3	88
8060	D	10	7.5	5	5	4	N	5	40	15	10	0	0	65	47	0.0	20.1	15.1	0.0	35.2	89
1277	A	10	7	5	4	5	N	6	40	10	10	0	0	60	56	0.0	23.4	11.7	0.0	35.2	90
10033	A	47.9	36	7	7	7	N	N	0	0	10	0	0	10	931	0.0	0.0	23.6	11.3	34.9	91
10034	A	47.9	36	7	7	7	N	N	0	0	10	0	0	10	932	0.0	0.0	23.6	11.3	34.9	92
6034	A	40.9	25	6	4	7	N	7	40	10	1.1	0	0	51.1	89	0.0	24.8	10.1	0.0	34.9	93
4274	A	48	36	6	6	7	N	4	0	0	1.1	0	0	1.1	1191	0.0	24.7	10.1	0.0	34.8	94
4677	A	56.9	33.9	5	5	5	N	4	12	0	0.4	0	0	12.4	721	0.0	24.8	10.0	0.0	34.8	95
2695	A	53.9	35	N	N	N	N	4	0	0	0	0	0	0	1477	0.0	22.9	11.5	0.0	34.4	96
2108	D	10	7	5	4	5	N	6	40	10	10	0	0	60	61	0.0	22.9	11.5	0.0	34.4	97
8134	A	63.7	38.3	5	4	6	N	N	0	10	0	0	0	10	918	0.0	23.6	8.8	1.9	34.4	98
7766	A	52.3	31.4	5	6	5	N	4	20.8	0	0.4	0	0	21.2	582	0.0	24.5	9.9	0.0	34.3	99
843	A	69.9	49	5	5	4	N	6	0	15	7.1	0	0	22.1	566	0.0	22.9	11.4	0.0	34.3	100

4.0 Algorithm Development

The new deficiency algorithm was developed using Excel spreadsheets to facilitate displaying results. The decision tree, flow chart, and source code for the algorithm are presented in Appendices A, B, and C, respectively. In this section, the procedures used to analyze the deficiency algorithm results and determine the optimum deficiency criteria and weight factors are described. Besides documenting the current deficiency algorithm, description of these procedures may be helpful when developing deficiency algorithms for other bridge populations.

In the first section below, the use of a graphical interface is described that enabled quick adjustment of the deficiency criteria and weight factors and provided a global view of the impact on the bridge population. The next section describes spot checking the accuracy of the calculations and reviewing the results for reasonableness using a detailed list of deficient bridges. And finally, a sensitivity analysis of the weight factors is presented that was used to determine the range of values that best differentiated each type of deficiency without overshadowing other deficiencies.

Graphical Interface

The graphical interface has two pages: an input screen and an output screen.

- <u>Input Screen</u> A ranked list of deficient bridges for a particular population of bridges (Figure 4-1) was calculated by

    - Selecting the bridge "owner" and "region"
    - Clicking the "Filter Data" button
    - Typing in the deficiency criteria (shaded in yellow) for each of the four types of deficiencies. For each deficiency, a minimum, intermediate, and desirable criteria value was specified. (See Figure 4-2.)
    - Typing in the deficiency points (shaded in orange) for each minimum and intermediate deficiency criteria. The desirable criteria were automatically assigned zero deficiency points.
    - Typing in an "X" under ADT, ADTT, and Detour Length Factors opposite each applicable criteria
    - Typing in the ADT and Detour Length Factors
    - Checking or unchecking the check-boxes at the bottom regarding closed bridges and ADT/DL factors

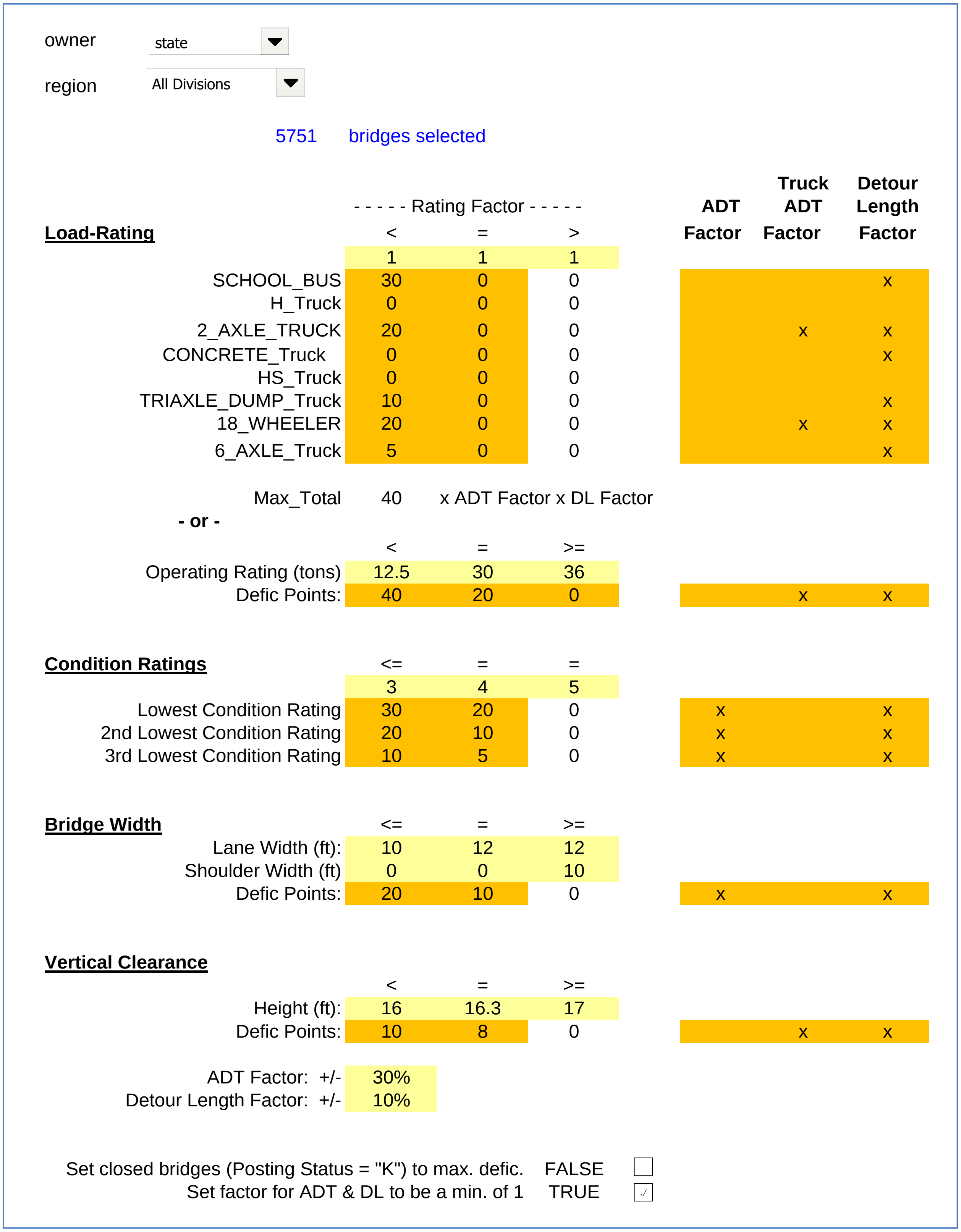


Figure 4-1. Graphical interface screen one: Deficiency criteria and weights.

- Output Screen The distribution of deficient bridges was displayed by

    - Clicking the “Calc Defic’s” button and waiting 10 to 20 seconds for the algorithm to execute

    The order of replacement (e.g. load deficient bridges replaced before vertical clearance deficient bridges) was displayed by

    - Moving the slider to the top so that “number of bridges to replace” = 0
    - Clicking in the middle of the slider to display the distribution of replaced bridges, 10 at a time

Detailed Bridge List

Detailed information about each bridge was shown on another sheet of the spreadsheet (Figure 4-3). All of the fields are shown in Figure 4-3; however, many fields can be collapsed on the actual spreadsheet to so that all information fits on one screen. All of the fields from the bridge database used to calculate deficiency are displayed. In addition, information derived from the database such as load rating factors, percent rank ADT, minimum condition, and whether the bridge is “underwidth” (less than the desirable bridge width criteria) is also displayed.

The points for each deficiency (load, condition, width, and vertical clearance), total deficiency and deficiency rank are shown on the right-hand side of this sheet (Figure 4-3). On the extreme right-hand side of the sheet the individual bridge deficiencies are indicated in color-coded columns.

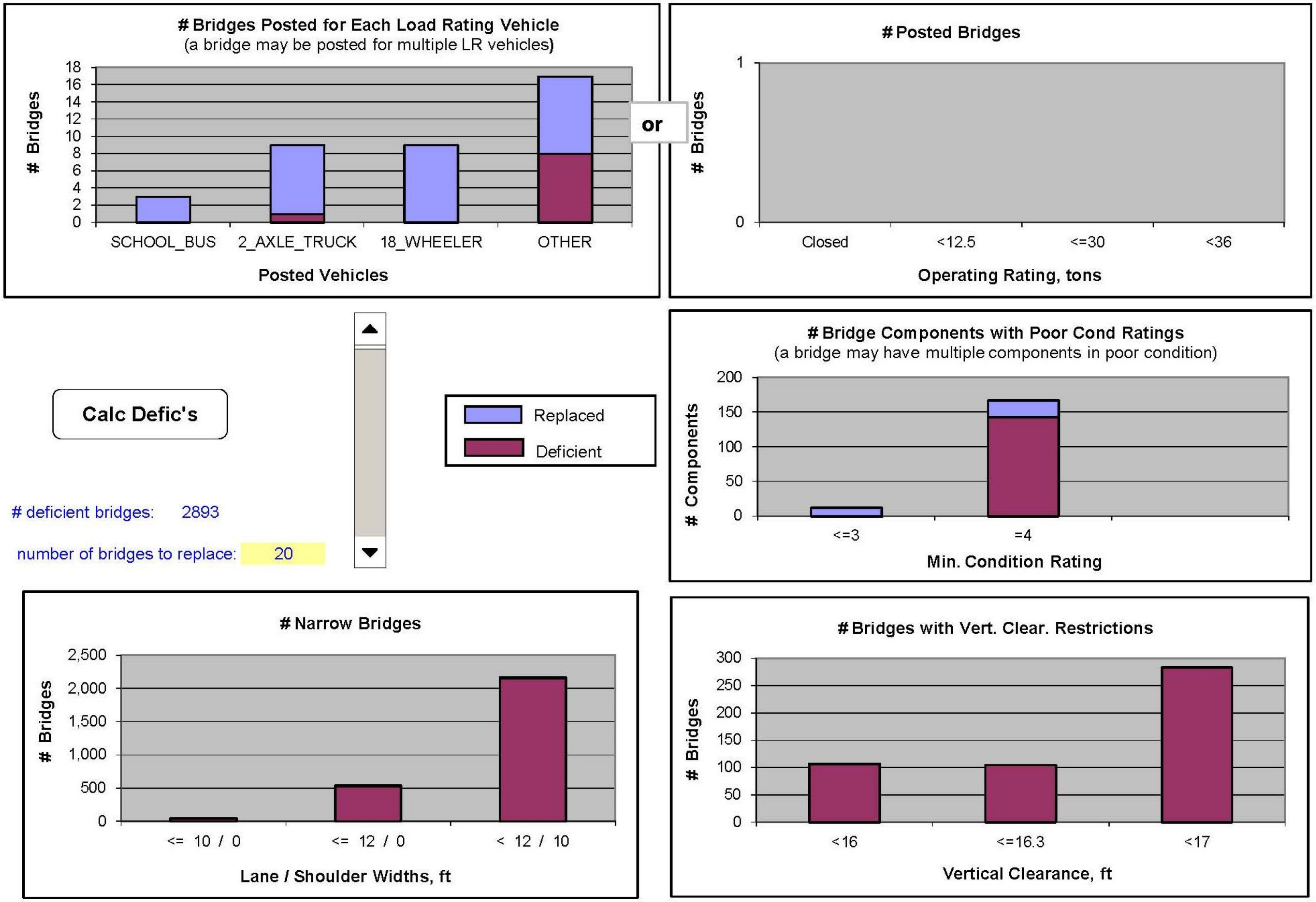


Figure 4-2. Graphical interface screen two: Distribution of deficient and "replaced" bridges.

Bin	Op_Status	Owner	Div	County	Service_On	Facil_Carried	Route_On	Location	Service_Under	Features_Intersected	Route_Under	Year_Blt	Design_Load	Span_Kind	Span_Type	Sufficiency_Rating
1841	O	State	1	Etowah Co	Hwy	AL 179	SR 00179	AL 179 & WADE CREEK	Water	WADE CREEK		1938	Other or U	Stl	Stringer	24.9
529	O	State	7	Houston Co	Hwy	SR 52 MP 65	SR 00052	.8 MI. EAST U.S. 84	RR	C.S.X. RAILROAD		1928	H 15	Conc	T Beam	2
635	O	State	5	Chilton Co	Hwy	SR 22	SR 00022	2.9 MI E JCT SR 191	Water	BENSON CREEK		1929	H 10	Timber	Stringer	6
2736	O	State	6	Autauga Co	Hwy	AL 206	SR 00206	IN PRATTVILLE	Water	AUTAUGA CREEK		1942	H 15	Conc	T Beam	7
1842	O	State	1	Etowah Co	Hwy	AL 179	SR 00179	6 . 3 MI N JCT US 278	Water	BRANCH		1938	Other or U	Stl	Stringer	29.9
504	O	State	5	Chilton Co	Hwy	SR 22	SR 00022	0.4 MI E JCT SR 191	Water	MIDDLE MULBERRY CREEK		1928	H 10	Timber	Stringer	6.3
7608	O	State	4	Calhoun Co	Hwy	SUMMERALL	CO 00000	0.2 MI W JCT SR 21	Hwy	US 431	US 0043	1962	HS 20	Conc	T Beam	13.7
2037	O	State	1	Etowah Co	Hwy	AL 77	SR 00077	AL 77 & HORTON CREEK	Water	HORTON CREEK		1939	H 15	Stl	Stringer	26.4
1765	O	State	5	Chilton Co	Hwy	SR 22	SR 00022	0.5 MI E JCT SR 191	Relief	MULBERRY CREEK RELIEF		1938	H 10	Timber	Stringer	8.5
4507	O	State	1	Etowah Co	Hwy	US 278	US 00278	US 278 @ WALNUT GROVE	Water	BLACK WARRIOR RELIEF		1935	H 15	Stl	Stringer	4
19818	O	State	6	Montgomery Co	Hwy	AL0601 (OLD	SR 00601	1.4MI N. OF JACKSON ST.	RR	CSX RAIL ROAD		1937	Other or U	Conc	Stringer	28.8
503	O	State	2	Lawrence Co	Hwy	SR 20	SR 00020	9.6 MI E JCT SR 33	Water	FOX CREEK		1928	H 15	Conc	T Beam	17
1394	O	State	3	Jefferson Co	Hwy-Ped	US 78	SR 00005	US 78 & VILLAGE CREEK	RR-Water	VILLAGE CK & FRISCO RR		1936	H 20	Stl	Stringer	2
1798	O	State	1	Cherokee Co	Hwy	AL 68	SR 00068	AL 68 & MILL CREEK	Water	MILL CREEK		1938	H 15	Stl Cont	Stringer	11
784	O	State	1	Jackson Co	Hwy	SR 35	SR 00035	0.5 MI N JCT SR40 & SR35	Water	TENNESSEE RIVER		1930	H 15	Stl	Truss -Thru	7.6
474	O	State	3	St. Clair Co	Hwy	US 78	US 00078	.2 MI E.COOK SPRINGS RD	Water	CANE CREEK		1928	H 15	Conc	T Beam	18.7
615	O	State	4	Chambers Co	Hwy	US 29	US 00029	4 MI N JCT CO 70	Water	OSANIPPA CREEK		1929	H 15	Conc	T Beam	6.9
2712	O	State	3	Walker Co	Hwy	AL 69	SR 00069	AL 69 & WARRIOR RIVER	Water	SIPSEY FORK WARIOR RIVER		1942	H 15	Stl Cont	Stringer	4
6588	O	State	2	Lawrence Co	Hwy	SR 20	SR 00020	9.6 MI E JCT SR 33	Water	FOX CREEK		1959	HS 20	Conc	T Beam	15
10132	O	State	3	Blount Co	Hwy	AL 75	SR 00075	.8 MI.NO CO RD 39	Water	CHAMPION CREEK		1929	H 15	Conc	T Beam	3
10102	O	State	9	Baldwin Co	Hwy	SR 182	SR 00182	1 MI W SR 59	Water	LITTLE LAGOON PASS		1969	HS 20	Conc	Stringer	20.9
7365	O	State	2	Lawrence Co	Hwy	SR 20	SR 00020	4.7 MI E JCT SR 33	Water	MALLARD CREEK		1961	HS 20	Conc	T Beam	15
9367	O	State	4	Talledega Co	Hwy	US 280	US 00280	TOWN OF CHILDERSBURG	RR	SOUTHERN RAILROAD		1935	H 15	Conc	T Beam	15
5816	O	State	5	Tuscaloosa Co	Hwy	US 82	US 00082	4.9 MI E TUSC CO LINE	Water	SIPSEY RIVER		1957	HS 20	Stl Cont	Stringer	6
12793	O	State	9	Baldwin Co	Hwy	US 98	US 00098	254' S COUNTY ROAD 24	Water	TURKEY BRANCH		1982	HS 20	Conc	Stringer	47.5
502	O	State	2	Lawrence Co	Hwy	SR 20	SR 00020	4.7 MI E JCT SR 33	Water	MALLARD CREEK		1928	H 15	Conc	T Beam	45.1
770	O	State	3	Shelby Co	Hwy	AL 25	SR 00025	AL 25 AT VINCENT SCHOOL	RR	ACLC LINE RAILROAD		1930	H 15	Conc	T Beam	63.4
1665	O	State	3	Jefferson Co	Hwy	AL 269	SR 00269	.1 MI. SO. POWHATAN RD	Water	SHORT CREEK		1937	H 15	Stl	Stringer	2
4658	O	State	3	Blount Co	Hwy	AL 79	SR 00079	.3 MI.NO.LOUUST FK CL	Water	BLACKBURN FK WARR RV		1953	H 15	Stl Cont	Stringer	44.6
1072	O	State	3	St. Clair Co	Hwy	US 11	US 00011	3.5 MI. NO. US 231	Water	GULF CREEK		1934	H 15	Stl Cont	Stringer	52.3
1368	O	State	2	Lauderdale Co	Hwy	US 72	US 00072	2.4 KM W JCT SR 101	Water	BLUEWATER CREEK		1924	H 15	Stl	Stringer	40.4

Figure 4-3. Detailed list of deficient bridges.

Bin	ADT_on	Percent_Trucks_on	Detour_Length_On	ADT_under	Percent_Trucks_under	Detour_Length_Under	Posting_Status	Op_Rating	H_Truck	2_AXLE_TRUCK	TRIAXLE_DUMP	CONCRETE_Truck	18_WHEELER	6_AXLE	SCHOOL_BUS	Deck_Cond	Super_Struc_Cond	Sub_Struc_Cond	Culvert_Cond	Channel_Cond	Width_on	Num_lanes_on	Direction_of_Traffic	OverClearance	UnderClearance	RF_HS_Truck	RF_H_Truck_Rating	RF_2_AXLE_TRUCK_Rating	RF_TRIAXLE_DUMP_Truck_Rating	RF_CONCRETE_Truck_Rating	RF_18_WHEELER_Truck_Rating	RF_6_AXLE_Truck_Rating
1841	1910	5	6				P	3	3	3	3	3	3	3	3	3	3	5	N	5	29.3	2	2-way	99.99	0	0.08	0.15	0.1017	0.08	0.0909	0.075	0.0714
529	5360	4	3				P	15	15	15	15	15	15	15	15	4	5	4	N	N	20	2	2-way	99.99	22.24	0.42	0.75	0.5085	0.4	0.4545	0.375	0.3571
635	3500	19	57				P	3	15	21	20	18	32	32	18	5	5	3	N	7	27.7	2	2-way	99.99	0	0.08	0.745	0.6949	0.5333	0.5576	0.795	0.7571
2736	6510	6	6				P	15	15	15	15	15	15	15	15	6	5	2	N	5	25.9	2	2-way	99.99	0	0.42	0.75	0.5085	0.4	0.4545	0.375	0.3571
1842	2380	5	6				P	6	6	6	6	6	6	6	6	4	7	5	N	4	31.2	2	2-way	99.99	0	0.17	0.3	0.2034	0.16	0.1818	0.15	0.1429
504	2510	19	57				P	6.1	15	21	20	18	32	32	18	5	5	4	N	7	27.7	2	2-way	99.99	0	0.17	0.745	0.6949	0.5333	0.5576	0.795	0.7571
7608	7300	5	1	19580	8	1	P	13	13	13	13	13	13	13	13	7	7	4	N	N	27.9	2	2-way	99.99	18.99	0.36	0.65	0.4407	0.3467	0.3939	0.325	0.3095
2037	15190	9	3				P	6.9	3.8	3.4	5.1	5.1	8.7	7.9	4.5	6	4	5	N	7	35.1	2	2-way	99.99	0	0.19	0.19	0.1153	0.136	0.1545	0.2175	0.1881
1765	2510	19	57				P	6.1	23	35	32	32	40	41	30	5	7	4	N	7	27.8	2	2-way	99.99	0	0.17	1.17	1.1932	0.8507	0.9545	0.995	0.969
4507	5880	25	19				D	15	33	42	48	42	66	69	45	4	3	4	N	7	24	2	2-way	99.99	0	0.42	1.63	1.4339	1.2693	1.2636	1.655	1.6357
19818	50	0	199				D	40	25	37	40	36	51	53	29	3	3	3	N	N	23.9	2	2-way	99.99	22	1.1	1.24	1.2678	1.056	1.0788	1.2725	1.25
503	7005	15	0				D	3	30	43	37	38	62	57	35	4	3	6	N	7	20	2	1-way	99.99	0	0.08	1.495	1.461	0.9947	1.1424	1.55	1.3619
1394	37460	7	3				D		40	52	47	47	78	76	50	3	5	6	N	5	40	4	2-way	99.99	22		2.02	1.7458	1.2533	1.4121	1.9425	1.8024
1798	1510	11	6				D	10								4	5	4	N	3	24	2	2-way	99.99	0	0.28						
784	7750	8	1				E	10								5	4	5	N	6	19.7	2	1-way	14.1	0	0.28						
474	1150	5	3				D	10	10	10	10	10	10	10		6	6	4	N	4	20	2	2-way	99.99	0	0.28	0.5	0.339	0.2667	0.303	0.25	0.2381
615	7940	3	8				D	10								4	6	5	N	5	20	2	2-way	99.99	0	0.28						
2712	3530	22	14				A	6	6	6	6	6	6	6	6	4	6	4	N	5	24	2	2-way	99.99	0	0.17	0.3	0.2034	0.16	0.1818	0.15	0.1429
6588	7005	15	18				A	24	41	48	53	48	79	76	50	4	4	6	N	7	27.9	2	1-way	99.99	0	0.67	2.03	1.6271	1.4213	1.4455	1.97	1.8119
10132	7590	9	3				D	10								5	4	4	N	4	29.9	2	2-way	99.99	0	0.28						
10102	4350	2	98				A	36	20	37	42	44	67	61	38	4	4	5	N	5	28	2	2-way	99.99	0	1	0.995	1.2644	1.1253	1.3424	1.6825	1.4571
7365	6530	17	18				A	24	38	46	52	46	75	71	44	4	4	6	N	7	27.9	2	1-way	99.99	0	0.67	1.885	1.5559	1.384	1.4061	1.875	1.6786
9367	26390	12	1				D	10	10	10	10	10	10	10	10	4	4	4	N	N	67.9	5	2-way	99.99	21.58	0.28	0.5	0.339	0.2667	0.303	0.25	0.2381
5816	12990	16	6				D	10	10	10	10	10	10	10	10	4	4	7	N	6	27.8	2	2-way	99.99	0	0.28	0.5	0.339	0.2667	0.303	0.25	0.2381
12793	10680	4	4				A	48								7	7	4	N	4	27.6	2	2-way	99.99	0	1.33						
502	6530	17	0				A	50	30	42	37	38	62	57	35	4	4	6	N	7	23	2	1-way	99.99	0	1.39	1.5	1.4271	0.9947	1.1424	1.55	1.3619
770	6150	9	3				A	57								4	5	5	N	N	18	2	2-way	99.99	22.57	1.58						
1665	4700	10	3				D	10								4	5	4	N	7	24	2	2-way	99.99	0	0.28						
4658	5520	11	3				A	52	20	56	57	51	66	42	60	5	5	4	N	4	26	2	2-way	99.99	0	1.44	1	1.8983	1.52	1.5455	1.65	1
1072	1690	6	6				A	66								5	5	4	N	4	24	2	2-way	99.99	0	1.83						
1368	7055	9	0				A	41	33	39	38	38	54	52	39	4	5	4	N	6	23.7	2	1-way	99.99	0	1.14	1.665	1.3254	1.0187	1.1424	1.3375	1.2381

Figure 4-3. Detailed list of deficient bridges (continued).

																				Number of Deficiencies: Load Rating < Legal				Condition Rating			Lane/Shourlder Width			Vertical Clearance		
Bin	RF_SCHOOL_BUS_Rating	percent_rank_ADT_on	percent_rank_ADTT_on	percent_rank_DL_on	percent_rank_ADT_under	percent_rank_ADTT_under	percent_rank_DL_under	min_load_rating_factor	mind_cond	2nd_min_cond	3rd_min_cond	under_width	min_vert_clearance	Load_Defic	Cond_Defic	Width_Defic	Vert_Clear_Defic	**Total_Defic**	Rank	SCHOOL_BUS	2_AXLE_TRUCK	18_WHEELER	OTHER	<=3	=4	=5	<= 10 / 0	<= 12 / 0	< 12 / 10	<16	<=16.3	<17
1841	0.24	0.69	0.64	0.53				0.07	3	3	5	Y	99.99	57.2	55.9	8.2	0.0	121.4	1	1	1	1	1	2		1			1			
529	1.2	0.82	0.72	0.30				0.36	4	4	5	Y	22.24	57.2	34.3	22.9	0.0	114.4	2		1	1	1		2	1	1					
635	1.4	0.76	0.85	0.97				0.08	3	5	5	Y	99.99	57.2	38.0	10.3	0.0	105.6	3		1	1	1	1		2			1			
2736	1.2	0.84	0.79	0.53				0.36	2	5	5	Y	99.99	57.2	36.4	11.0	0.0	104.6	4		1	1	1	1		2			1			
1842	0.48	0.72	0.67	0.53				0.14	4	4	5	Y	99.99	57.2	34.1	7.3	0.0	98.5	5	1	1	1	1		2	1			1			
504	1.4	0.72	0.81	0.97				0.17	4	5	5	Y	99.99	57.2	24.8	10.1	0.0	92.1	6		1	1	1		1	2			1			
7608	1.04	0.86	0.78	0.09	0.58	0.56	0.33	0.31	4	7	7	Y	18.99	57.2	22.3	9.0	0.0	88.5	7		1	1	1		1				1			
2037	0.36	0.93	0.91	0.30				0.12	4	5	6	Y	99.99	57.2	24.1	5.4	0.0	86.7	8	1	1	1	1		1	1			1			
1765	2.376	0.72	0.81	0.97				0.17	4	5	7	Y	99.99	42.3	24.8	10.1	0.0	77.2	9			1	1		1	1			1			
4507	3.6	0.83	0.92	0.91				0.42	3	4	4	Y	99.99	0.0	58.3	13.0	0.0	71.3	10					1	2			1				
19818	2.336	0.11		0.99				1.06	3	3	3	Y	22	0.0	60.0	10.3	0.0	70.3	11					3				1				
503	2.816	0.85	0.89					0.08	3	4	6	Y	99.99	0.0	43.6	21.8	0.0	65.4	12					1	1		1					
1394	4.032	0.98	0.94	0.30				1.25	3	5	5	Y	22	0.0	37.1	24.7	0.0	61.8	13					1		2	1					
1798		0.66	0.69	0.53				0.28	3	4	4	Y	99.99	0.0	49.7	11.0	0.0	60.7	14					1	2			1				
784		0.86	0.84	0.09				0.28	4	5	5	Y	14.1	0.0	22.4	22.4	12.2	57.0	15						1	2	1			1		
474		0.63	0.60	0.30				0.24	4	4	6	Y	99.99	0.0	31.0	20.6	0.0	51.6	16						2		1					
615		0.87	0.73	0.66				0.28	4	5	5	Y	99.99	0.0	25.1	25.1	0.0	50.3	17						1	2	1					
2712	0.48	0.77	0.87	0.84				0.14	4	4	5	Y	99.99	0.0	37.2	12.4	0.0	49.5	18						2	1		1				
6588	3.992	0.85	0.89	0.90				0.67	4	4	6	Y	99.99	0.0	39.2	9.9	0.0	49.1	19						2				1			
10132		0.86	0.85	0.30				0.28	4	4	4	Y	99.99	0.0	40.8	8.2	0.0	49.1	20						3				1			
10102	3.04	0.79	0.64	0.98				1.00	4	4	5	Y	99.99	0.0	38.7	10.3	0.0	49.0	21						2	1			1			
7365	3.544	0.84	0.90	0.90				0.67	4	4	6	Y	99.99	0.0	39.1	9.8	0.0	48.9	22						2				1			
9367	0.8	0.97	0.95	0.09				0.24	4	4	4	Y	21.58	0.0	41.1	7.1	0.0	48.2	23						3				1			
5816	0.8	0.91	0.93	0.53				0.24	4	4	6	Y	99.99	0.0	37.6	10.2	0.0	47.8	24						2				1			
12793		0.90	0.79	0.45				1.33	4	4	7	Y	99.99	0.0	36.7	10.0	0.0	46.7	25						2				1			
502	2.824	0.84	0.90					0.99	4	4	6	Y	99.99	0.0	32.6	13.6	0.0	46.1	26						2			1				
770		0.84	0.82	0.30				1.58	4	5	5	Y	22.57	0.0	23.1	23.1	0.0	46.1	27						1	2	1					
1665		0.81	0.80	0.30				0.28	4	4	5	Y	99.99	0.0	34.0	11.3	0.0	45.4	28						2	1		1				
4658	4.8	0.82	0.84	0.30				1.00	4	4	5	Y	99.99	0.0	34.4	10.3	0.0	44.7	29						2	1			1			
1072		0.67	0.65	0.53				1.83	4	4	5	Y	99.99	0.0	33.3	11.1	0.0	44.4	30						2	1		1				
1368	3.12	0.85	0.84					1.02	4	4	5	Y	99.99	0.0	32.7	11.7	0.0	44.4	31						2	1		1				

Figure 4-3. Detailed list of deficient bridges (continued).

Example

Using the criteria and weights described in the sections above and summarized in Figure 4-1, deficiency points are calculated for all state-owned bridges. The list of deficient bridges is "replaced" 10 bridges at a time by clicking on the slider in Figure 4-2. The bar charts in Figure 4-2 present an overview of the impact on the state bridge population of replacing the 10 most-deficient bridges; and of replacing the next 10 most-deficient bridges, etc. More detailed information on particular deficiencies is presented in the color-coded column tally sheet (Figure 4-3). Table 4-1 below summarizes the results of incrementally replacing the most-deficient bridges in the population.

Table 4-1. Effect on Bridge Population of Replacing

# Most-Deficient Bridges Replaced	Effect on Bridge Population
first 10	Half of the 17 load-posted bridges replaced, including all 3 of the bridges posted for school buses, 8 of the 9 bridges posted for two-axle trucks all 9 of the bridges posted for 18-wheelers Remaining load-deficient bridges are posted for primarily triaxle dump trucks
next 10 (total = 20)	11 of the 12 bridges with condition ratings = 3 now replaced
next 160 (total = 180)	All of the 167 bridges with condition ratings = 4 replaced 15 of the 17 load-posted bridges now replaced
next 80 (total = 260)	All 47 of the narrow bridges (20-foot curb-to-curb decks) now replaced All 17 load-posted bridges now replaced

The deficiency criteria and weight factors presented in the example therefore implement the following bridge replacement priorities (in order of decreasing importance):

- bridges load-posted for school buses, two-axle, trucks and 18-wheelers and bridges in extremely poor condition (condition ratings = 4)
- bridges in poor condition (condition ratings = 4)
- narrow bridges and bridges load-posted for less common trucks (triaxle dump truck, concrete, and six-axle)

5.0 Sensitivity Study

Utilizing the most recent data from the Alabama Bridge Information Database (ABIMS) database, several iterations of the current ALDOT weights and three scenarios (presented by ALDOT personnel) were generated using increasing levels of ADT and detour factoring.

Procedure

The current ALDOT weights and the three scenarios are listed in Table 5-1 with respect to the importance placed on each of the four deficiency areas: load, condition, width, and vertical clearance.

Table 5-1. Weight Factors for Each Scenario

	Load	Condition	Width	Vertical Clearance
ALDOT	40%	40%	10%	10%
Scenario I	40%	20%	20%	20%
Scenario II	40%	30%	20%	10%
Scenario III	40%	30%	15%	15%

These weights are then used in conjunction with nine different levels of ADT and detour factoring to produce comparisons of the movement of individual bridges within the ranking of each case. This produces 36 different runs to completely saturate all possible outcomes. Table 5-2 presents the nine levels of ADT and detour factoring that were used for this analysis.

Table 5-2. ADT and Detour Length Weights

Run	1	2	3	4	5	6	7	8	9
ADT	0%	10%	20%	30%	40%	0%	30%	30%	30%
Detour	0%	0%	0%	0%	0%	20%	10%	20%	30%

Candidates

The analysis was focused on "state-owned" structures within all divisions of the Alabama Department of Transportation. This database (State-Owned Structures) was populated by more than 5,000 structures. When compared against the parameters used to denote a deficiency in terms of load, condition, width, and vertical clearance, 2906 structures were deficient in one or more of these areas.

The average replacement rate per year in Alabama varies from 20 to 40 structures per year. In order to project out for three years of construction, a base of 30 structures per year will be used for analysis. This will be further simplified to observing the first 100 structures of the ranking while analyzing the weights and factors when prioritizing replacement policy.

Deterioration Algorithm

The validation for the deterioration model used for this analysis was developed by Dr. James Richardson, Principal Investigator, as an extension of his previous work with Dr. Daniel Turner (1991a). A prioritized ranking of bridges based on ALDOT's weighting criteria was generated using data from a previous year. This data was then presented to the ALDOT bridge maintenance personnel who validated the result by indicating that structures identified as deficient and with high priority had been replaced or had been scheduled for replacement. This assists in the validation process in that the algorithm is generating the same replacement sequence as the current ALDOT system.

Analysis

The analysis is a series of observations. The first being the different runs using the nine levels (combinations) of ADT and detour factor. This will assist in determining the proper level to which set the ADT and detour factor within the model. The next step in the analysis process is to graph the individual deficiencies (load, condition, width, and vertical clearance) along with the total deficiency in order to observe each deficiency's behavior. These graphs and their interpretation can be used to convey the results to the Alabama Bridge Management team that will determine the best scenario or a derivation to use as the final model which will be instituted.

ADT and Detour Factors

A quasi-sensitivity analysis can be conducted by generating the bridge ranking based on ADT and detour factors of zero. This creates a baseline where ADT and detour have no effect on the calculation of total deficiency. ADT is then introduced into the model in increments of 10% up to a level where the ranking stabilizes and no further changes in a structure's position is observed. Tables 5-3, 5-4, 5-5, and 5-6 display the runs for the first 100 structures for the different scenarios. Through this process, the ADT factor stabilizes between 20% and 30%. The interpretation is that between 20% and 30% the emphasis placed on the amount of ADT has it maximum effect on a structures ranking. ADT factors of 30% to 40% are relatively identical indicating that factor is not producing any additional effect that would cause structure to advance in the ranking. This is considered a stable ranking, bridges with large ADT and high deficiency scores will increase toward the front of the ranking and those structures with low ADT and moderate deficiency scores will continue to progress to the end of the ranking. Increasing the ADT factor would only widen this gap and not generate any additional permutations. Additionally, increasing the ADT factor to an immense proportion could have the effect of masking highly deficiency bridges with low ADT scores and focus attention to those structures which may be less deficient but have large ADT levels. Therefore, the ADT factor should be kept to a range where it is a discriminator in like cohort groups.

Detour factor is then applied to an already established ADT level of 30%. Detour is the factor applied when a structure is not capable of carrying a specified load and an alternate route must be utilized. The greater the amount of distance, "detour" that must be covered the greater the effect of the detour factor will have on the deficiency score. Detour levels of 10%, 20%, and 30% are applied. Tables 5-7, 5-8, 5-9, and 5-10 display the effects of an increasing detour factor. The greatest change in the ranking appears when detour is increased from 0% to 10%. Factors of 10% to 20% are the next greatest change and 20% to 30% show signs of stabilization. Increasing the detour factor beyond 30% would start to have the same effect as mentioned for the ADT factor. Structures with large detour lengths could mask structures that are more deficient.

Table 5-3. Bridge Rankings for Current ALDOT Weights, No Detour Factor, ADT Factor = 0, 0.2, 0.3, 0.4

	ALDOT(40,40,10,10) (no ADT, no Detour)	ALDOT(40,40,10,10) (no Detour), ADT 20%	ALDOT(40,40,10,10) (no Detour) ADT 30%	ALDOT(40,40,10,10) (no Detour) ADT 40%
Rank	BIN	BIN	BIN	BIN
1	1841	1841	1841	1841
2	2736	2736	2736	2736
3	635	635	635	635
4	529	529	529	529
5	19818	1842	1842	1842
6	1842	19818	504	504
7	504	504	7608	7608
8	7608	7608	19818	2037
9	2037	2037	2037	19818
10	503	503	503	503
11	1798	1798	1798	1798
12	4507	4507	4507	4507
13	3202	3202	3202	3202
14	1765	1765	1765	1765
15	1394	2844	2844	2844
16	18612	1394	1394	1394
17	18614	18612	18612	18612
18	2844	18614	18614	18614
19	4947	4947	4947	4947
20	5618	5618	5618	5618
21	4975	4975	4975	4975
22	2534	2534	2534	2534
23	474	474	474	474
24	784	784	784	784
25	944	944	944	944
26	2853	2853	2853	2853
27	10132	10132	10132	10132
28	9367	9367	9367	9367
29	502	502	502	502
30	1368	1368	1368	1368
31	885	885	885	885
32	1072	1072	1072	1072
33	1665	1665	1665	1665
34	2627	2627	2627	2627
35	2712	2712	2712	2712
36	3130	3130	3130	3130
37	4658	4658	4658	4658
38	12793	12793	12793	12793
39	5816	5816	5816	5816
40	10102	10102	10102	10102
41	6473	6473	6473	6473
42	6588	6588	6588	6588
43	7365	7365	7365	7365
44	4994	4994	4994	4994
45	10493	10493	10493	10493
46	615	615	615	615
47	770	770	770	770
48	798	798	798	798
49	14407	14407	14407	14407
50	10083	10083	10083	10083
51	617	617	617	617
52	1268	1268	1268	1268
53	3817	3817	3817	3817
54	3818	3818	3818	3818
55	8060	8060	8060	8060
56	8648	8648	8648	8648
57	5430	5430	5430	5430
58	10690	10690	10690	10690
59	476	476	476	476
60	486	486	486	486
61	1717	1717	1717	1717
62	1739	1739	1739	1739
63	1917	1917	1917	1917
64	1918	1918	1918	1918
65	2566	2566	2566	2566
66	2567	2567	2567	2567
67	5977	5977	5977	5977
68	1911	1911	1911	1911
69	271	271	271	271
70	843	843	843	843
71	915	915	915	915
72	1029	1029	1029	1029
73	1071	1071	1071	1071
74	1273	1273	1273	1273
75	1274	1274	1274	1274
76	1275	1275	1275	1275
77	1276	1276	1276	1276
78	1277	1277	1277	1277
79	1442	1442	1442	1442
80	1613	1613	1613	1613
81	1664	1664	1664	1664
82	1695	1695	1695	1695
83	1797	1797	1797	1797
84	1897	1897	1897	1897
85	1898	1898	1898	1898
86	2013	2013	2013	2013
87	2108	2108	2108	2108
88	2253	2253	2253	2253
89	2320	2320	2320	2320
90	2408	2408	2408	2408
91	2588	2588	2588	2588
92	2666	2666	2666	2666
93	2695	2695	2695	2695
94	3899	3899	3899	3899
95	4333	4333	4333	4333
96	5222	5222	5222	5222
97	5973	5973	5973	5973
98	6062	6062	6062	6062
99	8466	8466	8466	8466
100	8467	8467	8467	8467

Table 5-4. Bridge Rankings for Scenario I, No Detour Factor, ADT Factor = 0, 0.2, 0.3, 0.4

	Senario I (40,20,20,20) (no ADT, no Detour)	Senario I (40,20,20,20) (no Detour), ADT 20%	Senario I (40,20,20,20) (no Detour) ADT 30%	Senario I (40,20,20,20) (no Detour) ADT 40%
Rank	BIN	BIN	BIN	BIN
1	1841	1841	1841	1841
2	529	529	529	529
3	2736	2736	2736	2736
4	635	635	635	635
5	1842	1842	1842	1842
6	504	504	504	504
7	7608	7608	7608	7608
8	2037	2037	2037	2037
9	3202	2844	2844	2844
10	1765	3202	3202	3202
11	4947	1765	1765	1765
12	5618	4947	4947	4947
13	4975	5618	5618	5618
14	2844	784	784	784
15	2534	4975	4975	4975
16	19818	2534	2534	2534
17	503	19818	19818	19818
18	944	503	503	503
19	2853	944	944	944
20	18612	2853	2853	2853
21	784	18612	18612	18612
22	1394	1394	1394	1394
23	1798	2035	2035	2035
24	4507	10033	10033	10033
25	474	10034	10034	10034
26	615	10641	10641	10641
27	770	1798	1798	1798
28	798	4507	4507	4507
29	2035	2273	2273	2273
30	10033	474	474	474
31	10034	10493	10493	10493
32	10641	1901	1901	1901
33	18614	1387	1387	1387
34	10083	1709	1709	1709
35	502	615	615	615
36	617	770	770	770
37	8323	798	798	798
38	8324	6487	6487	6487
39	2273	7544	7544	7544
40	1268	8118	8118	8118
41	1368	8188	8188	8188
42	3817	8327	8327	8327
43	3818	10868	10868	10868
44	13809	14407	14407	14407
45	885	19153	19153	19153
46	1072	8326	8326	8326
47	1665	8965	8965	8965
48	2627	10428	10428	10428
49	2712	6229	6229	6229
50	3130	14159	14159	14159
51	8060	18614	18614	18614
52	10493	6378	6378	6378
53	10132	4850	4850	4850
54	4658	15061	15061	15061
55	17042	5461	5461	5461
56	6574	2648	2648	2648
57	12793	928	928	928
58	8648	9542	9542	9542
59	5816	7638	7638	7638
60	9367	7852	7852	7852
61	10102	8797	8797	8797
62	5430	9528	9528	9528
63	6473	9625	9625	9625
64	6588	10174	10174	10174
65	7365	13682	13682	13682
66	476	6449	6449	6449
67	486	7250	7250	7250
68	1901	10427	10427	10427
69	4994	10083	10083	10083
70	10690	6437	6437	6437
71	1387	6438	6438	6438
72	1717	6495	6495	6495
73	1739	6496	6496	6496
74	1917	6499	6499	6499
75	1918	6500	6500	6500
76	2566	8187	8187	8187
77	2567	9527	9527	9527
78	5977	502	502	502
79	1911	617	617	617
80	1709	7329	7329	7329
81	226	7330	7330	7330
82	227	9902	9902	9902
83	228	8976	8976	8976
84	249	8323	8323	8323
85	271	8324	8324	8324
86	278	7561	7561	7561
87	280	8155	8155	8155
88	366	9543	9543	9543
89	426	9544	9544	9544
90	429	4756	4756	4756
91	430	5068	5068	5068
92	438	7984	7984	7984
93	469	8186	8186	8186
94	481	1268	1268	1268
95	485	1368	1368	1368
96	517	3817	3817	3817
97	519	3818	3818	3818
98	543	7320	7320	7320
99	556	4794	4794	4794
100	616	14647	14647	14647

Table 5-5. Bridge Rankings for Scenario II, No Detour Factor, ADT Factor = 0, 0.2, 0.3, 0.4

	Senario II (40,30,20,10) (no ADT, no Detour)	Senario II (40,30,20,10) (no Detour), ADT 20%	Senario II (40,30,20,10) (no Detour) ADT 30%	Senario II (40,30,20,10) (no Detour) ADT 40%
Rank	BIN	BIN	BIN	BIN
1	1841	1841	1841	1841
2	529	529	529	529
3	2736	2736	2736	2736
4	635	635	635	635
5	1842	1842	1842	1842
6	504	504	504	504
7	7608	7608	7608	7608
8	19818	2037	2037	2037
9	2037	19818	19818	2844
10	3202	3202	2844	19818
11	1765	1765	3202	3202
12	503	503	1765	1765
13	4947	2844	503	503
14	5618	1798	1798	1798
15	1394	4507	4507	4507
16	1798	4947	4947	4947
17	4507	5618	5618	5618
18	4975	1394	1394	1394
19	2844	4975	4975	4975
20	2534	2534	2534	2534
21	18612	18612	18612	18612
22	784	784	784	784
23	944	944	944	944
24	2853	2853	2853	2853
25	474	474	474	474
26	18614	18614	18614	18614
27	615	615	615	615
28	770	770	770	770
29	798	798	798	798
30	502	502	502	502
31	1368	10132	10132	10132
32	10083	1368	1368	1368
33	617	10083	10083	10083
34	10132	617	617	617
35	885	9367	9367	9367
36	1072	885	885	885
37	1665	1072	1072	1072
38	2627	1665	1665	1665
39	2712	2627	2627	2627
40	3130	2712	2712	2712
41	9367	3130	3130	3130
42	4658	4658	4658	4658
43	1268	1268	1268	1268
44	3817	3817	3817	3817
45	3818	3818	3818	3818
46	12793	12793	12793	12793
47	5816	5816	5816	5816
48	2035	2035	2035	2035
49	8060	8060	8060	8060
50	10033	10033	10033	10033
51	10034	10034	10034	10034
52	10102	10102	10102	10102
53	10493	10493	10493	10493
54	10641	10641	10641	10641
55	6473	6473	6473	6473
56	6588	6588	6588	6588
57	7365	7365	7365	7365
58	4994	4994	4994	4994
59	8648	8648	8648	8648
60	5430	5430	5430	5430
61	8323	2273	2273	2273
62	8324	476	476	476
63	2273	486	486	486
64	476	1717	1717	1717
65	486	1739	1739	1739
66	10690	1917	1917	1917
67	1717	1918	1918	1918
68	1739	2566	2566	2566
69	1917	2567	2567	2567
70	1918	5977	5977	5977
71	2566	1911	1911	1911
72	2567	271	271	271
73	5977	843	843	843
74	1911	915	915	915
75	13809	1029	1029	1029
76	271	1071	1071	1071
77	843	1273	1273	1273
78	915	1274	1274	1274
79	1029	1275	1275	1275
80	1071	1276	1276	1276
81	1273	1277	1277	1277
82	1274	1442	1442	1442
83	1275	1613	1613	1613
84	1276	1664	1664	1664
85	1277	1695	1695	1695
86	1442	1797	1797	1797
87	1613	1897	1897	1897
88	1664	1898	1898	1898
89	1695	2013	2013	2013
90	1797	2108	2108	2108
91	1897	2253	2253	2253
92	1898	2320	2320	2320
93	2013	2408	2408	2408
94	2108	2588	2588	2588
95	2253	2666	2666	2666
96	2320	2695	2695	2695
97	2408	3899	3899	3899
98	2588	4333	4333	4333
99	2666	5222	5222	5222
100	2695	5973	5973	5973

Table 5-6. Bridge Rankings for Scenario III, No Detour Factor, ADT Factor = 0, 0.2, 0.3, 0.4

Rank	Senario III (40,30,15,15) (no ADT, no Detour)	Senario III (40,30,15,15) (no Detour), ADT 20%	Senario III (40,30,15,15) (no Detour) ADT 30%	Senario III (40,30,15,15) (no Detour) ADT 40%
	BIN	BIN	BIN	BIN
1	1841	1841	1841	1841
2	529	529	529	529
3	2736	2736	2736	2736
4	635	635	635	635
5	1842	1842	1842	1842
6	504	504	504	504
7	7608	7608	7608	7608
8	19818	2037	2037	2037
9	2037	19818	19818	2844
10	3202	3202	2844	19818
11	1765	1765	3202	3202
12	503	2844	1765	1765
13	4507	503	503	503
14	1798	1798	1798	1798
15	4947	4507	4507	4507
16	5618	4947	4947	4947
17	4975	5618	5618	5618
18	2844	4975	4975	4975
19	1394	784	784	784
20	784	1394	1394	1394
21	18612	18612	18612	18612
22	2534	2534	2534	2534
23	944	944	944	944
24	2853	2853	2853	2853
25	474	474	Sea	474
26	18614	18614	18614	18614
27	10493	10493	10493	10493
28	502	502	502	502
29	14407	10132	10132	10132
30	10641	9367	9367	9367
31	10034	615	615	615
32	10033	770	770	770
33	2035	798	798	798
34	798	2035	2035	2035
35	770	10033	10033	10033
36	615	10034	10034	10034
37	10132	10641	10641	10641
38	1368	14407	14407	14407
39	9367	1368	1368	1368
40	3130	885	885	885
41	2712	1072	1072	1072
42	2627	1665	1665	1665
43	1665	2627	2627	2627
44	1072	2712	2712	2712
45	885	3130	3130	3130
46	10083	10083	10083	10083
47	4658	4658	4658	4658
48	617	617	617	617
49	12793	12793	12793	12793
50	2273	2273	2273	2273
51	5816	5816	5816	5816
52	10102	10102	10102	10102
53	7365	6473	6473	6473
54	6588	6588	6588	6588
55	6473	7365	7365	7365
56	4994	4994	4994	4994
57	3818	1268	1268	1268
58	3817	3817	3817	3817
59	1268	3818	3818	3818
60	8060	8060	8060	8060
61	8648	8648	8648	8648
62	5430	5430	5430	5430
63	10690	10690	10690	10690
64	1901	476	476	476
65	486	486	486	486
66	476	1901	1901	1901
67	5977	1387	1387	1387
68	2567	1717	1717	1717
69	2566	1739	1739	1739
70	1918	1917	1917	1917
71	1917	1918	1918	1918
72	1739	2566	2566	2566
73	1717	2567	2567	2567
74	1387	5977	5977	5977
75	1911	1911	1911	1911
76	1709	1709	1709	1709
77	19153	271	271	271
78	10868	843	843	843
79	8467	915	915	915
80	8466	1029	1029	1029
81	8327	1071	1071	1071
82	8188	1273	1273	1273
83	8118	1274	1274	1274
84	7544	1275	1275	1275
85	6487	1276	1276	1276
86	6062	1277	1277	1277
87	5973	1442	1442	1442
88	5222	1613	1613	1613
89	4333	1664	1664	1664
90	3899	1695	1695	1695
91	2695	1797	1797	1797
92	2666	1897	1897	1897
93	2588	1898	1898	1898
94	2408	2013	2013	2013
95	2320	2108	2108	2108
96	2253	2253	2253	2253
97	2108	2320	2320	2320
98	2013	2408	2408	2408
99	1898	2588	2588	2588
100	1897	2666	2666	2666

Table 5-7. Bridge Rankings for Current ALDOT Weights, ADT Factor = 0.3, Detour Factor = 0, 0.1, 0.2, 0.3

	ALDOT (40,40,10,10) (no Detour) ADT 30%	ALDOT (40,40,10,10) ADT 30%, Detour 10%	ALDOT (40,40,10,10) ADT 30%, Detour 20%	ALDOT (40,40,10,10) ADT 30%, Detour 30%
Rank	BIN	BIN	BIN	BIN
1	1841	1841	1841	1841
2	2736	2736	2736	2736
3	635	635	635	635
4	529	529	529	529
5	1842	1842	1842	1842
6	504	7608	7608	7608
7	7608	504	2037	2037
8	19818	2037	504	504
9	2037	19818	503	503
10	503	503	4507	4507
11	1798	4507	3202	3202
12	4507	3202	2844	2844
13	3202	1798	1765	1765
14	1765	1765	1798	1798
15	2844	2844	19818	1394
16	1394	1394	1394	19818
17	18612	18612	784	784
18	18614	4975	4975	9367
19	4947	784	9367	4975
20	5618	4947	2534	10132
21	4975	5618	4947	2534
22	2534	18614	10132	4947
23	474	2534	18612	944
24	784	944	944	502
25	944	9367	5618	2853
26	2853	10132	2853	5618
27	10132	474	474	474
28	9367	2853	502	1368
29	502	502	18614	10493
30	1368	1368	1368	5816
31	885	885	5816	12793
32	1072	1665	12793	6473
33	1665	5816	885	18612
34	2627	2712	1665	885
35	2712	12793	6473	1665
36	3130	4658	10493	4658
37	4658	6473	4658	6588
38	12793	2627	2712	7365
39	5816	1072	6588	14407
40	10102	6588	7365	2712
41	6473	7365	10102	10102
42	6588	10102	2627	4994
43	7365	10493	4994	2627
44	4994	4994	1072	18614
45	10493	3130	14407	1072
46	615	14407	615	615
47	770	615	770	770
48	798	770	3130	8648
49	14407	798	798	798
50	10083	617	617	617
51	617	8648	8648	5430
52	1268	3817	5430	3130
53	3817	3818	476	8134
54	3818	5430	8134	476
55	8060	1268	3817	2866
56	8648	8060	3818	486
57	5430	476	486	1695
58	10690	10690	10690	2550
59	476	486	1268	9044
60	486	10083	2866	2253
61	1717	8134	1695	10690
62	1739	1739	2253	8133
63	1917	1695	1739	2013
64	1918	1917	2013	5006
65	2566	1918	2550	1739
66	2567	2253	1897	3817
67	5977	2013	1898	3818
68	1911	1911	1664	1897
69	271	1897	8060	1898
70	843	1898	1917	1664
71	915	1664	1918	9229
72	1029	2866	9044	2682
73	1071	1613	8133	5603
74	1273	2666	2682	7630
75	1274	271	1613	7631
76	1275	2550	2666	9444
77	1276	915	5006	1613
78	1277	1717	271	7627
79	1442	1273	1911	2666
80	1613	1274	915	1917
81	1664	1275	9229	1918
82	1695	1276	1273	7766
83	1797	6062	1274	271
84	1897	2320	1275	4754
85	1898	5977	1276	915
86	2013	1277	6062	3033
87	2108	2682	2320	6470
88	2253	2588	5603	6471
89	2320	1442	3033	5140
90	2408	2408	9444	7232
91	2588	5222	7766	1911
92	2666	3033	7630	1273
93	2695	2695	7631	1274
94	3899	3024	1277	1275
95	4333	2566	7627	1276
96	5222	2567	3024	7238
97	5973	1029	2588	6062
98	6062	9044	1442	5992
99	8466	8133	5140	6355
100	8467	5006	2408	2320

Table 5-8. Bridge Rankings for Scenario I, ADT Factor = 0.3, Detour Factor = 0, 0.1, 0.2, 0.3

Rank	Senario I (40,20,20,20) (no Detour) ADT 30% BIN	Senario I (40,20,20,20) ADT 30%, Detour 10% BIN	Senario I (40,20,20,20) ADT 30%, Detour 20% BIN	Senario I (40,20,20,20) ADT 30%, Detour 30% BIN
1	1841	1841	1841	1841
2	529	529	529	529
3	2736	2736	2736	2736
4	635	635	635	635
5	1842	1842	1842	1842
6	504	7608	7608	7608
7	7608	504	504	2037
8	2037	2037	2037	504
9	2844	2844	2844	2844
10	3202	3202	3202	784
11	1765	1765	784	3202
12	4947	784	1765	1765
13	5618	4975	4975	2035
14	784	4947	4947	4975
15	4975	5618	503	503
16	2534	2534	5618	2273
17	19818	503	2534	4947
18	503	944	2035	2534
19	944	2853	944	10641
20	2853	2035	10641	1394
21	18612	10641	2273	5618
22	1394	1394	1394	944
23	2035	2273	2853	10493
24	10033	19818	10493	2853
25	10034	10033	4507	1901
26	10641	10034	10033	4507
27	1798	4507	10034	10428
28	4507	10493	1901	10033
29	2273	18612	1798	10034
30	474	1798	10428	14407
31	10493	1901	19818	8327
32	1901	474	1387	9542
33	1387	1387	14407	1387
34	1709	10428	8327	1798
35	615	14407	18612	10427
36	770	8327	9542	2648
37	798	1709	474	928
38	6487	6487	2648	9543
39	7544	2648	10427	9544
40	8118	928	928	15061
41	8188	9542	6487	6487
42	8327	8118	15061	474
43	10868	615	1709	1709
44	14407	15061	8118	6378
45	19153	10427	6378	8118
46	8326	770	9543	615
47	8965	19153	9544	9902
48	10428	6378	615	770
49	6229	8326	770	18612
50	14159	8188	19153	19153
51	18614	10868	8326	6437
52	6378	798	9902	6438
53	4850	7544	8188	8326
54	15061	6229	6437	19818
55	5461	8965	6438	8797
56	2648	9543	7638	6449
57	928	9544	8797	7638
58	9542	9902	6449	8188
59	7638	7638	10868	5068
60	7852	8797	798	10868
61	8797	6449	6229	8976
62	9528	6437	7544	502
63	9625	6438	8976	7852
64	10174	4850	7852	798
65	13682	7852	5068	6229
66	6449	14159	502	7320
67	7250	5461	8965	7544
68	10427	8976	7329	13809
69	10083	502	7330	7329
70	6437	10174	10174	7330
71	6438	7329	4850	8142
72	6495	7330	7320	10174
73	6496	6499	617	8965
74	6499	6500	6499	9926
75	6500	617	6500	617
76	8187	8187	5461	1368
77	9527	7250	8187	7984
78	502	6495	13809	7561
79	617	6496	14159	6499
80	7329	5068	6495	6500
81	7330	9527	6496	9050
82	9902	9528	7561	8971
83	8976	7561	7250	4850
84	8323	18614	1368	8187
85	8324	7320	7984	9367
86	7561	13682	9527	5461
87	8155	8155	8155	10132
88	9543	8323	8971	7250
89	9544	8324	9050	10573
90	4756	7984	10132	6495
91	5068	9625	11672	6496
92	7984	13809	9367	11672
93	8186	1368	9528	9286
94	1268	9905	8323	8155
95	1368	9906	8324	9270
96	3817	10132	8142	885
97	3818	8971	9286	1665
98	7320	11672	9905	9527
99	4794	4756	9906	6574
100	14647	885	9270	14159

Table 5-9. Bridge Rankings for Scenario II, ADT Factor = 0.3, Detour Factor = 0, 0.1, 0.2, 0.3

Rank	Senario II (40,30,20,10) (no Detour) ADT 30% BIN	Senario II (40,30,20,10) ADT 30%, Detour 10% BIN	Senario II (40,30,20,10) ADT 30%, Detour 20% BIN	Senario II (40,30,20,10) ADT 30%, Detour 30% BIN
1	1841	1841	1841	1841
2	529	529	529	529
3	2736	2736	2736	2736
4	635	635	635	1842
5	1842	1842	1842	635
6	504	7608	7608	7608
7	7608	504	2037	2037
8	2037	2037	504	504
9	19818	3202	3202	3202
10	2844	1765	2844	2844
11	3202	2844	1765	503
12	1765	19818	503	1765
13	503	503	4507	4507
14	1798	4507	1394	1394
15	4507	1798	19818	784
16	4947	1394	784	1798
17	5618	784	1798	4975
18	1394	4975	4975	19818
19	4975	4947	474	474
20	2534	474	4947	4947
21	18612	5618	5618	2534
22	784	18612	2534	9367
23	944	2534	944	502
24	2853	944	9367	5618
25	474	2853	502	10132
26	18614	502	10132	944
27	615	10132	2853	1368
28	770	9367	18612	615
29	798	1368	1368	2853
30	502	615	615	770
31	10132	770	770	5816
32	1368	885	885	885
33	10083	1665	1665	1665
34	617	2712	5816	12793
35	9367	2627	2712	6473
36	885	4658	12793	4658
37	1072	1072	4658	2712
38	1665	798	6473	10493
39	2627	5816	2627	6588
40	2712	12793	6588	7365
41	3130	6473	1072	2627
42	4658	10102	7365	10102
43	1268	6588	798	18612
44	3817	7365	10102	1072
45	3818	617	10493	798
46	12793	4994	4994	4994
47	5816	3130	617	617
48	2035	10493	8648	8648
49	8060	18614	5430	5430
50	10033	3817	3817	14407
51	10034	3818	3818	2035
52	10102	1268	3130	3817
53	10493	8648	1268	3818
54	10641	8060	14407	476
55	6473	5430	2035	10641
56	6588	10083	476	486
57	7365	476	8060	2273
58	4994	486	18614	1268
59	8648	14407	486	1695
60	5430	2035	10641	1739
61	2273	1739	1739	2866
62	476	1917	1695	8060
63	486	1918	2253	2253
64	1717	10641	1917	8134
65	1739	1911	1918	3130
66	1917	1695	2013	2013
67	1918	1717	2866	2550
68	2566	2253	1897	1897
69	2567	2013	1898	1898
70	5977	5977	1664	1664
71	1911	1897	1911	1917
72	271	1898	2273	1918
73	843	1664	8134	1613
74	915	1613	2550	2666
75	1029	2666	1613	1911
76	1071	271	2666	271
77	1273	915	271	2682
78	1274	1273	915	915
79	1275	1274	1273	9044
80	1276	1275	1274	1273
81	1277	1276	1275	1274
82	1442	2566	1276	1275
83	1613	2567	6062	1276
84	1664	6062	2320	6062
85	1695	2320	1717	8133
86	1797	10033	2682	2320
87	1897	10034	1277	5006
88	1898	1277	10033	3033
89	2013	2588	10034	1277
90	2108	1442	5977	9229
91	2253	2408	2588	2588
92	2320	2866	1442	1442
93	2408	5222	2408	2408
94	2588	2550	3033	5603
95	2666	2695	5222	3024
96	2695	8134	3024	7766
97	3899	1029	2695	9444
98	4333	2682	9044	1717
99	5222	3033	8133	10033
100	5973	2108	5006	10034

Table 5-10. Bridge Rankings for Scenario III, ADT Factor = 0.3, Detour Factor = 0, 0.1, 0.2, 0.3

	Senario III (40,30,15,15) (no Detour) ADT 30%	Senario III (40,30,15,15) ADT 30%, Detour 10%	Senario III (40,30,15,15) ADT 30%, Detour 20%	Senario III (40,30,15,15) ADT 30%, Detour 30%
Rank	BIN	BIN	BIN	BIN
1	1841	1841	1841	1841
2	529	529	529	529
3	2736	2736	2736	2736
4	635	635	635	1842
5	1842	1842	1842	635
6	504	7608	7608	7608
7	7608	504	2037	2037
8	2037	2037	504	504
9	19818	3202	3202	3202
10	2844	1765	2844	2844
11	3202	2844	1765	1765
12	1765	19818	503	503
13	503	503	784	784
14	1798	4507	4507	4507
15	4507	784	19818	1394
16	4947	1798	1798	1798
17	5618	1394	1394	10493
18	4975	4975	4975	19818
19	784	4947	4947	4975
20	1394	18612	474	9367
21	18612	5618	10493	4947
22	2534	474	2534	2534
23	944	2534	5618	10132
24	2853	944	9367	474
25	Sea	9367	10132	14407
26	18614	10132	944	944
27	10493	2853	18612	502
28	502	10493	502	5618
29	10132	502	2853	1368
30	9367	1368	14407	2853
31	615	885	1368	5816
32	770	1665	885	12793
33	798	14407	5816	885
34	2035	2712	1665	6473
35	10033	4658	12793	1665
36	10034	5816	4658	4658
37	10641	12793	6473	18612
38	14407	2627	2712	2712
39	1368	1072	6588	6588
40	885	6473	7365	615
41	1072	6588	615	7365
42	1665	7365	2627	770
43	2627	10102	10102	2035
44	2712	615	770	10102
45	3130	770	1072	4994
46	10083	4994	4994	2627
47	4658	798	2035	1072
48	617	3130	798	2273
49	12793	18614	617	10641
50	2273	617	10641	798
51	5816	2035	2273	617
52	10102	10641	3130	8648
53	6473	3817	8648	5430
54	6588	3818	5430	1901
55	7365	1268	18614	476
56	4994	8648	3817	3817
57	1268	2273	3818	3818
58	3817	5430	1268	8134
59	3818	8060	476	486
60	8060	10033	10033	3130
61	8648	10034	10034	2866
62	5430	10083	8060	1268
63	10690	476	486	1695
64	476	486	8134	10690
65	486	10690	10690	2253
66	1901	1739	1901	1739
67	1387	8134	1739	2550
68	1717	1917	1695	2013
69	1739	1918	2253	10033
70	1917	1911	2866	10034
71	1918	1695	2013	1897
72	2566	2253	1917	1898
73	2567	2013	1918	1664
74	5977	1717	1897	9044
75	1911	1897	1898	8060
76	1709	1898	2550	1917
77	271	1664	1664	1918
78	843	5977	1911	8133
79	915	1613	1613	5006
80	1029	2666	2666	2682
81	1071	271	271	10428
82	1273	915	2682	1613
83	1274	2866	915	2666
84	1275	1273	1273	271
85	1276	1274	1274	1911
86	1277	1275	1275	9229
87	1442	1276	1276	915
88	1613	6062	6062	18614
89	1664	2320	2320	5603
90	1695	2550	9044	1273
91	1797	1277	8133	1274
92	1897	2566	1277	1275
93	1898	2567	1717	1276
94	2013	2588	3033	6062
95	2108	1442	5006	9444
96	2253	2408	2588	3033
97	2320	5222	1442	2320
98	2408	2682	2408	7766
99	2588	2695	5977	7630
100	2666	3033	9229	7631

Descriptive Results (Scenarios)

The next step in the analysis will employ ADT and detour at 30% and 20% respectively to describe the behavior of the individual deficiencies (load, condition, width, and vertical clearance). This behavior makes use of three dimensional graphs to visually observe the performance of the individual deficiencies from the first structure to structure 100. All four runs (ALDOT, Scenario I, Scenario II, Scenario III) are displayed as Figures 5-1, 5-2, 5-3, and 5-4.

Viewing Figures 5-1, 5-2, 5-3, and 5-4, the first observation is that based on a 100 point scale (without ADT or detour factor applied) the total deficiency points decrease to less than 50% of the possible value within 15 structures. The majority of this behavior is due to the elimination of load deficient structures early in the process. Load deficiency possesses 40% of the weight in all the scenarios; therefore, the behavior is the same for all iterations.

ALDOT Load and condition deficiency are the drivers for the first 30 structures. The first 10 structures are near or at the maximum number of possible deficiency points for load with the discriminator being the condition deficiency (decreases with every structure for the first 10 bridges). An important observation is the relationship with load and condition; the two measures appear to have a negative correlation. The relationship, with the exception of a few structures, either has a high load deficiency or a high condition deficiency but rarely have both present (which may indicate a bridge with a poor condition and has been posted to preserve its state).

Structures 30 to 100 have condition as the main contributor to the total deficiency since all load deficient structures have been identified in the initial set of 30 bridges. Width contributes to all 100 structures with varying levels of deficiency.

The width deficiency is a much more strenuous calculation compared to previous formulas and appears in most bridge deficiencies with few zero entries. The result of this adjusted calculation appears to have increased the baseline of the width deficiency. By observing the ALDOT graph and the subsequent scenarios, the width deficiency line is averaging 10 deficiency points with a few spikes to the maximum value (10 points coupled with an ADT factor). This negates some of the influence of the width deficiency since its average is has an almost uniform increase in all the structures scores.

Vertical clearance has little effect on the model, the instances of vertical are few and therefore the majority of the entries are zero.

Scenario I (40, 20, 20, 20) This scenario deviates the greatest amount from the contemporary ALDOT weighting. The behavior of load remains the same at 40% and allows load to drive the model again in the first 30 structures. Condition is at 20% weight and reduces its emphasis in the model (allowing width, vertical clearance, and condition to have equal influence). The result is a more balanced model when comparing the three variables. Width has a more uniform presence, while condition and vertical clearance compete for position (a negative correlation type behavior). This method also generates the most diverse raking when compared to ALDOT and the remaining two scenarios. This variety is due to the structures with vertical clearance are allowed to vie against condition equally and therefore brings more vertical clearance deficient structure to the foreground.

One limitation to this scenario is the equal impact of the three variables (condition, width, and vertical clearance). The actual priority of these variables may be skewed as a structure with a high vertical clearance and width deficiency (an older structure for example) may mask a structure with a poor condition.

Scenario II (40, 30, 20, 10) The step weighting approach for Scenario II can be viewed as a priority scale. Load and condition takes 40% and 30% of the total deficiency score, respectively. This portion of the bridge deficiency can be considered the "health" of the structure and therefore takes the majority of the weight.

Width is the next highest weighting with 20% of the total deficiency. Width has been discussed as a safety concern and a possible contributor to accidents in and around bridges when it is less than accommodating to present standards. The safety aspect and new building standards, while important to safety and meeting current construction goals, are not as detrimental to the structure (when compared to load and condition). This weighting allows width to have more influence in this model but not overshadow the importance of load and condition.

Vertical clearance has few instances throughout the population and therefore allowing it to remain at 10% will allow it to have influence and discriminate tie within like structures.

Scenario III (40, 30, 15, 15) Scenario III is a derivation of Scenario II. The difference is width and vertical clearance split the remaining 30% of the weight evenly. This approach allows vertical clearance (which has few instances) to have the same amount of influence as the width deficiency. The results are similar to Scenario II. The major difference is the level which width and vertical clearance can maximize when an extreme condition is present. Width is confined to a lower maximum score but is still uniform in nature and a few of the vertical clearance deficiencies meet the higher threshold.

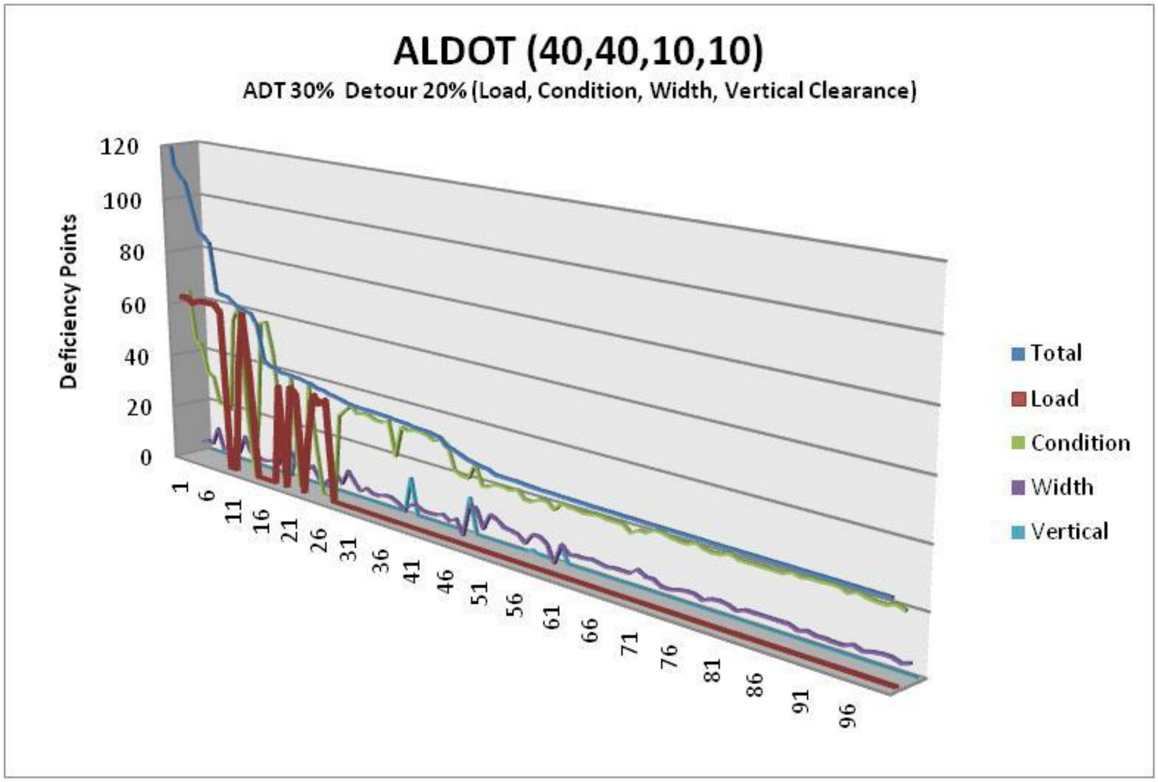


Figure 5-1. Deficiency points for each of 100 most-deficient bridges: ALDOT current weights.

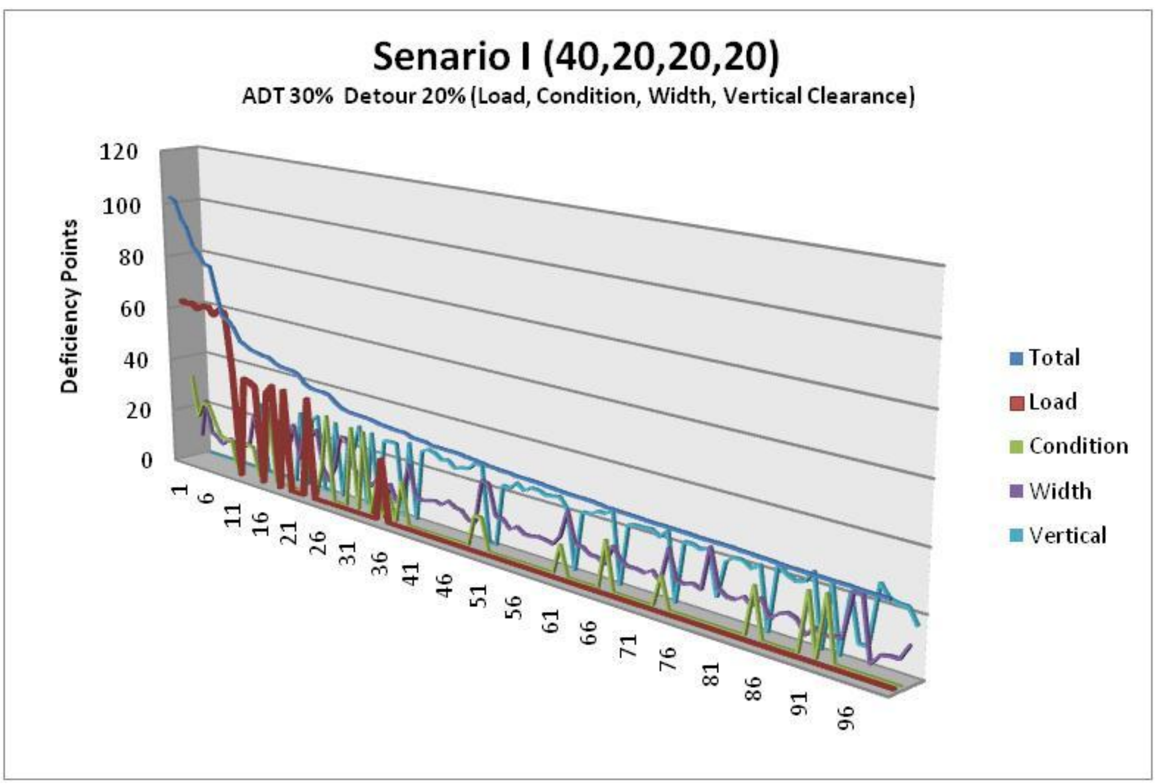


Figure 5-2. Deficiency points for each of 100 most-deficient bridges: Scenario I.

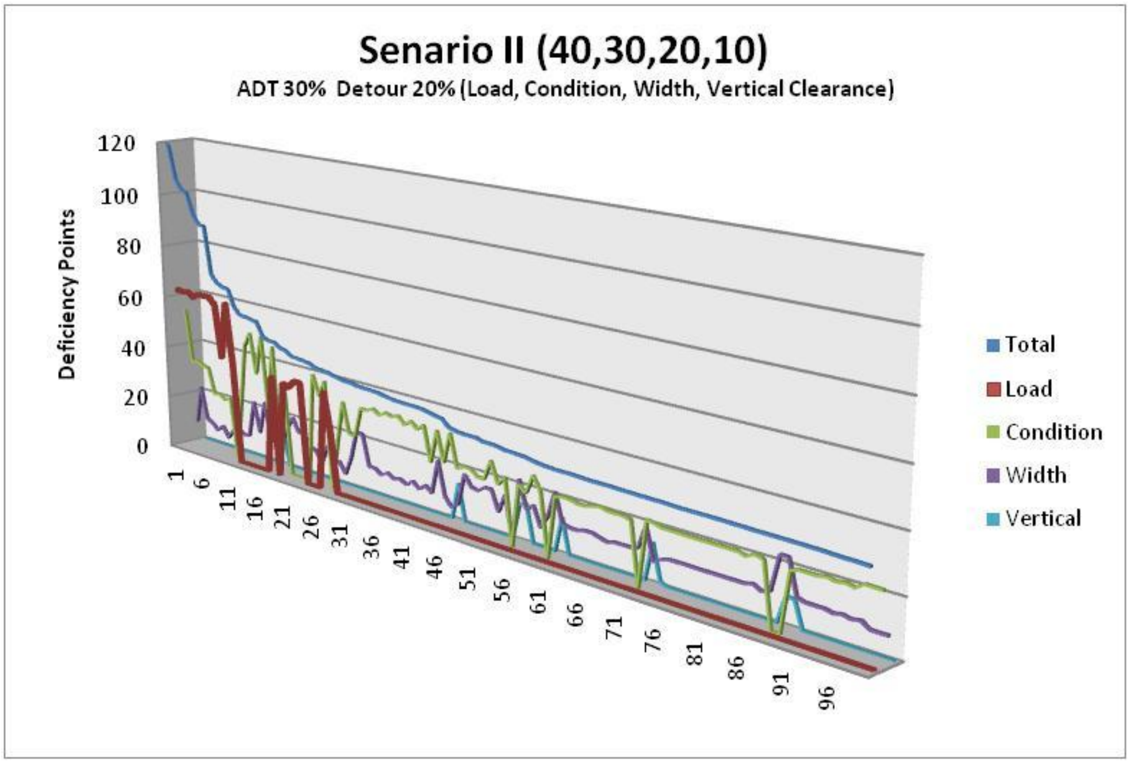


Figure 5-3. Deficiency points for each of 100 most-deficient bridges: Scenario II.

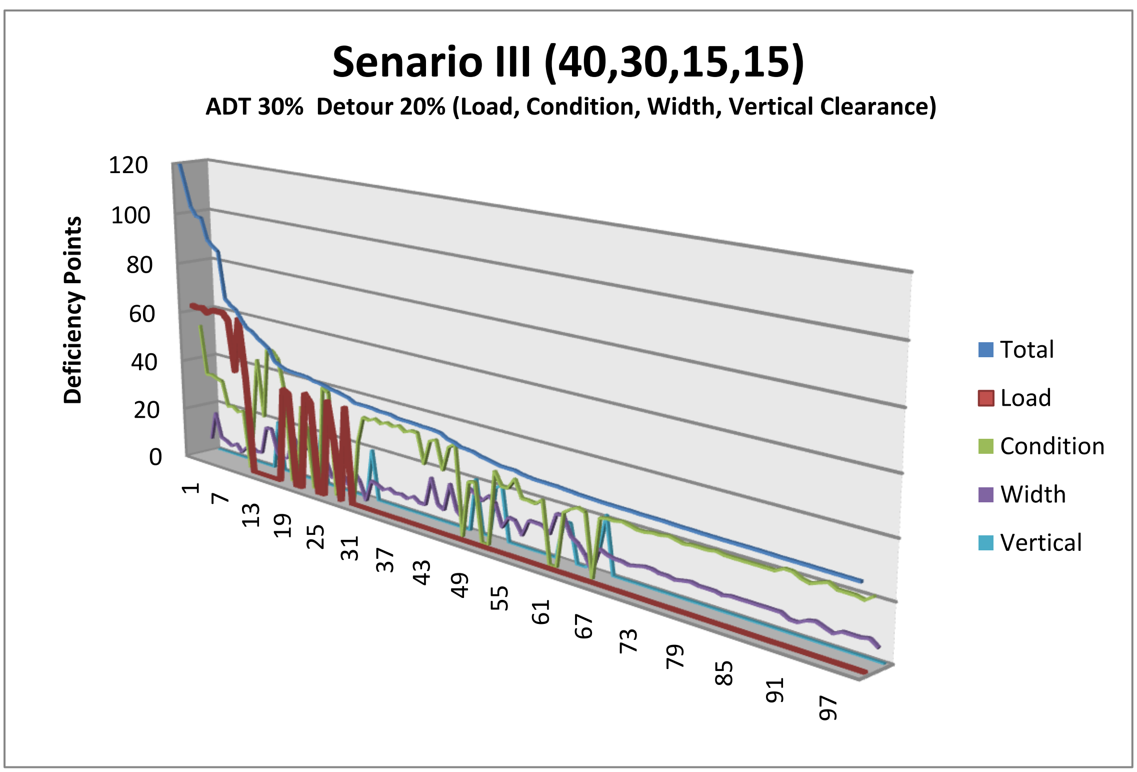


Figure 5-4. Deficiency points for each of 100 most-deficient bridges: Scenario III.

Research Recommendations

Based on the results discussed above, specific values for the ADT and detour factors and for the load, condition, width, and vertical clearance weights are presented in the following section. And finally, a recommendation to update these factors and weights as the bridge population changes is discussed.

Recommended Factors and Weights

ADT and detour factors can be set at 30% and 20% respectively. (See ***ADT and Detour Factors*** in Chapter 5 for a thorough explanation.) Scenario II gives a best fit, where the major factors to a structure's "health" (load and condition) are given the majority of the weight. Load is given a 10% gain over condition, accommodating the impact of certain vehicles types having to divert to another structure. (This can be viewed as an economic impact.) This difference is important with the calculation that is used to compute the condition deficiency.

Condition deficiency is given 30% total points with the caveat that as more components (deck, superstructure, substructure) reach threshold values this score can exceed the 30 points (prior to ADT factoring). Condition has 30% of the weight; it becomes the next most important driver after the load deficient structures are eliminated in approximately the first year. Condition deficient structures can lead to postings and closures; therefore, the priority placed on condition is commensurate to its weighting.

Width is increased from its current 10% contribution to 20%. The increase allows width to take into effect the more stringent criteria to determine width deficiency, which is becoming a priority within ALDOT. The benefit of using 20% as opposed to a higher and more equal rating with load and condition is to prevent a width deficient structure from becoming an equal priority with other structures with a load or condition deficiency. The concept to replace a bridge that is only exhibiting a width deficiency is rare, and therefore should be considered a "multiplier" to the total deficiency to elevate a structure that may be tied with other structures.

The instances of vertical clearance deficient structures in the inventory are low. The calculation also presents structures that are not a clearance constraint to themselves but may create a clearance constraint to a structure below the crossing (a bridge crossing over a road may cause a clearance restriction on that road while the bridge is otherwise fully functional). This may present a false representation if the route being crossed by the structure is not under the same constraints that are being used to calculate the current ranking. Leaving the vertical clearance weighting low will not convolute the ranking but will allow recognition of a possible vertical clearance deficiency.

Dynamic Adjustment

The situation that all the scenarios and the current ALDOT model display is the removal of the load deficient structures early in the process. This adjusted weighting from the 1991 research should not be considered a static weighting. As the load deficient structures are eliminated from the pool of possible candidates, this process should be repeated to best accommodate and reflect the demographics of the remaining inventory. Additionally, the current ADT numbers within the database may not reflect the true “possible” ADT numbers if a structure were not posted. The ADT measure is the current number of vehicles utilizing the structure, not taking into account the amount of traffic that is being diverted due to its limited capacity.

6.0 Conclusions and Recommendations

Objective and Scope of this Project

During validation of the 1991 ALDOT deficiency algorithm, the following comments were made by division bridge inspectors and county engineers:

- The ADT factor should be decreased.
- The inventory rating (the measure of load capacity used by the 1991 algorithm) does not reflect the effects of strengthening; perhaps only load-posted bridges should receive deficiency points.
- Especially narrow bridges should receive more deficiency points.
- Bridges with scour problems should receive deficiency points.
- The ADT numbers for county routes were not always accurate.

The deficiency algorithm developed in 1991 was used by ALDOT managers to select bridges for the bridge replacement program. Comments from these managers regarding the algorithm include:

- Not enough deficiency points were assigned to very narrow bridges.
- Deficiency points were not assigned to culverts.
- Load capacity was represented by inventory rating, but bridges are posted for load restrictions based on operating ratings.
- The goals for load capacity, width, and vertical clearance were not stringent enough.
- The goals and weight factors should be easy to update (without modifying the source code of the program).
- The deficiency equations were not intuitive (i.e. simple and based on a bridge's physical characteristics).

Every one of the "shortcomings" pointed out in the comments from the division bridge inspectors, the county engineers, and the ALDOT managers has been addressed in the revised algorithm presented in this report.

It is important to mention that this project only updated the deficiency algorithm for *state-owned* bridges. The population of state-owned bridges is very different from the population of locally-owned bridges (county, municipal, etc.), and the procedures for replacing state-owned bridges are different than the procedures for replacing locally-owned bridges. This is significant because the primary use of the deficiency algorithm is to help select bridges for replacement. This report was written to provide information useful for developing a similar algorithm for locally-owned bridges.

Principles of Algorithm Development

The preceding sections describe the mechanics of the new algorithm and document its validation. Lacking is a discussion of the bridge deficiency principles that evolved during algorithm 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 4, 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 Chapter 5.)

Algorithm Implementation

Once ALDOT managers approve the deficiency criteria and weights, the deficiency algorithm can be implemented on the Department's central computer. One of the comments made by a user of the 1991 algorithm, and a recommendation of this report, is to implement the deficiency algorithm so that the deficiency criteria, weights (deficiency points), and adjustment factors can be easily changed by an ALDOT manager, say the Bridge Maintenance Engineer. One method is to place the criteria, deficiency points, and adjustment factors in matrices, such as those shown in Figure 6-1 below.

		----- Criteria -----			----- Points -----			----- Factors -----		
		Max. Defic.	Intermed. Defic.	No Defic.	Max. Defic.	Intermed. Defic.	No Defic.	**ADT**	**ADTT**	**DL**
SCHOOL_BUS	1	1	0	0	30	0	0	0	0	0.1
H_Truck	2	1	0	0	0	0	0	0	0	0
2_AXLE_TRUCK	3	1	0	0	20	0	0	0	0.3	0.1
CONCRETE_Truck	4	1	0	0	0	0	0	0	0	0.1
HS_Truck	5	1	0	0	0	0	0	0	0	0
TRIAXLE_DUMP_Truck	6	1	0	0	10	0	0	0	0	0.1
18_WHEELER_Truck	7	1	0	0	20	0	0	0	0.3	0.1
6_AXLE_Truck	8	1	0	0	5	0	0	0	0	0.1
Operating Rating (tons)	9	12.5	30	36	40	20	0	0	0.3	0.1
Lowest Condition Rating	10	3	4	5	30	20	0	0.3	0	0.1
2nd Lowest Condition Rating	11	3	4	5	20	10	0	0.3	0	0.1
3rd Lowest Condition Rating	12	3	4	5	10	5	0	0.3	0	0.1
Lane Width	13	10	12	12	20	10	0	0.3	0	0.1
Shoulder Width	14	0	0	10						
Height	15	16	16.3	17	10	8	0	0	0.3	0.1

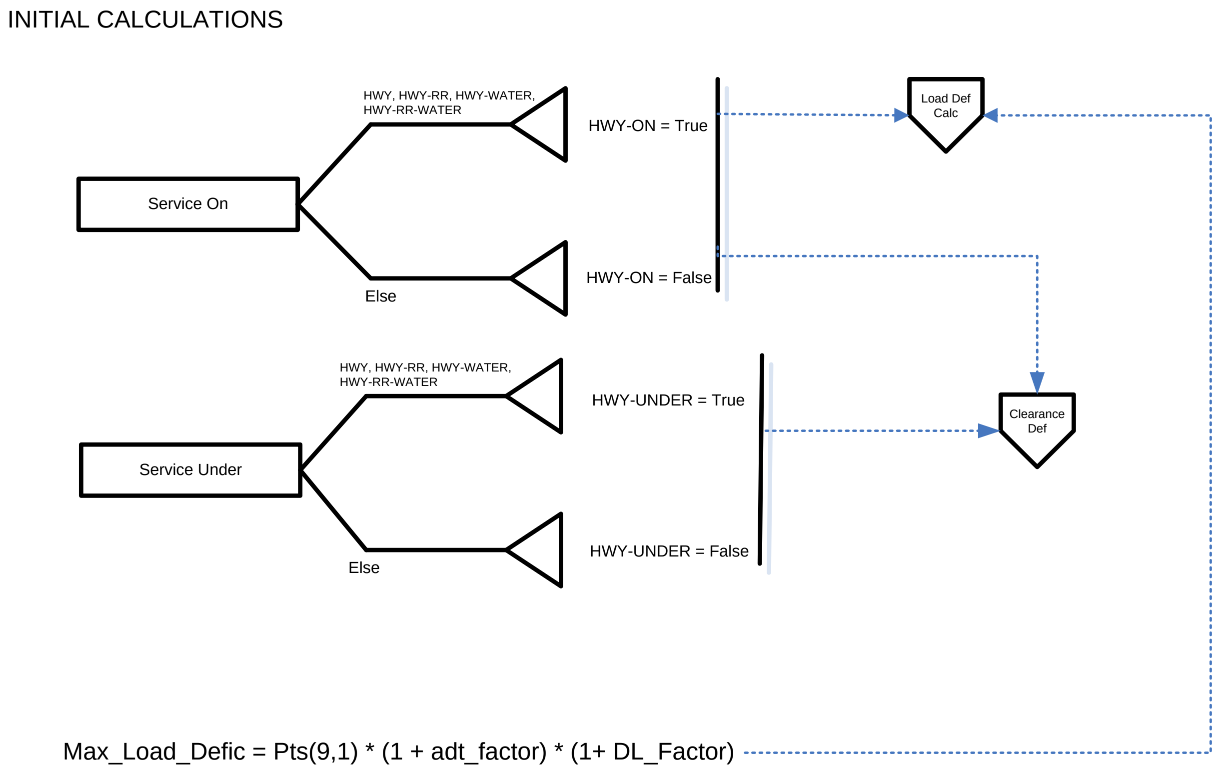
Figure 6-1. Criteria, deficiency points, and ADT/detour factor matrices for deficiency algorithm.

7.0 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. and Turner, D., *Development of Deficiency Point Algorithms for the Alabama Bridge Information Management System (Executive Summary)*, Bureau of Engineering Research Report #557-39, University of Alabama College of Engineering, 1991b, 16 pp.

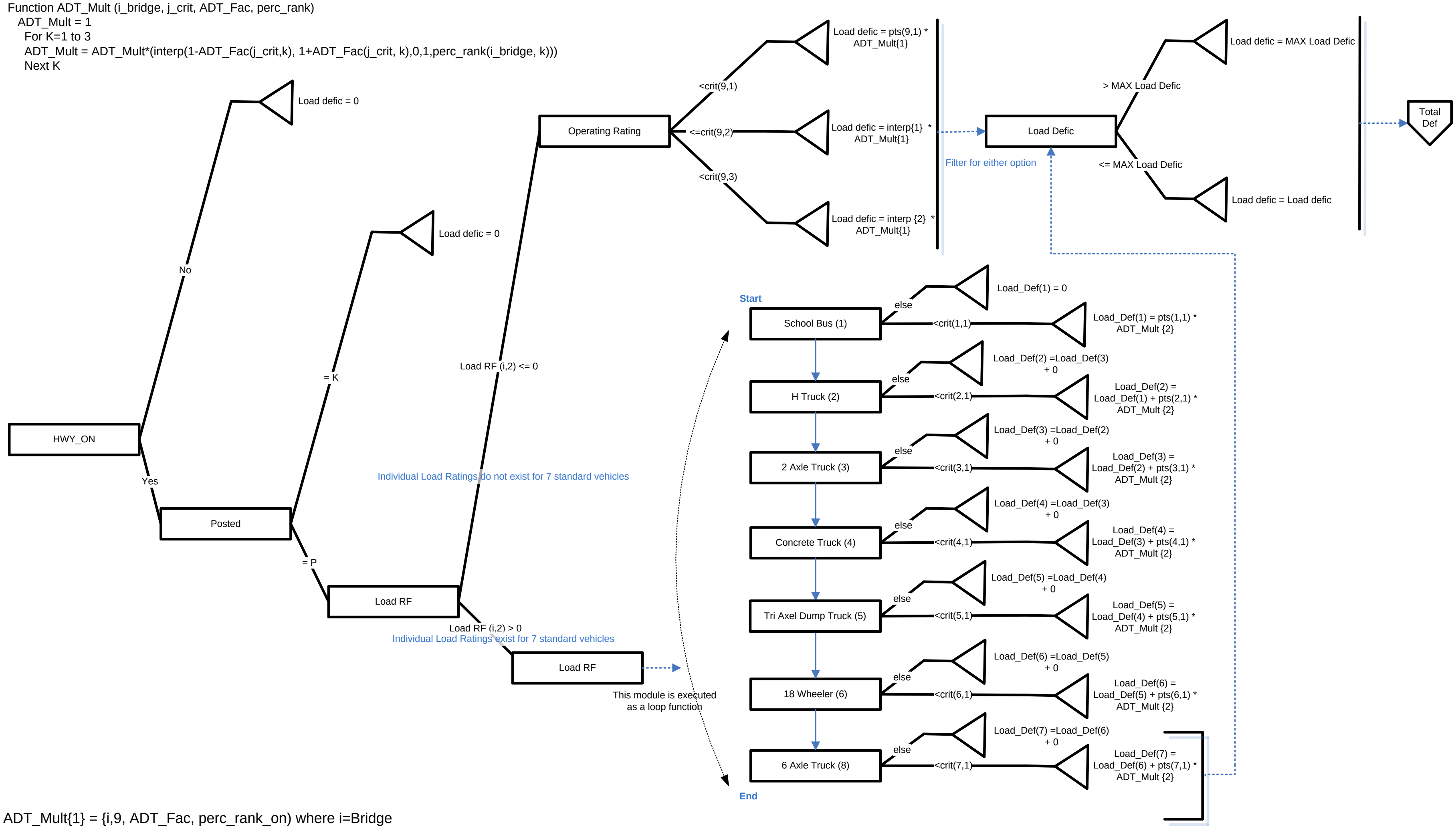
Appendix A: Decision Tree of Deficiency Algorithm



LOAD DEFICIENCY

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

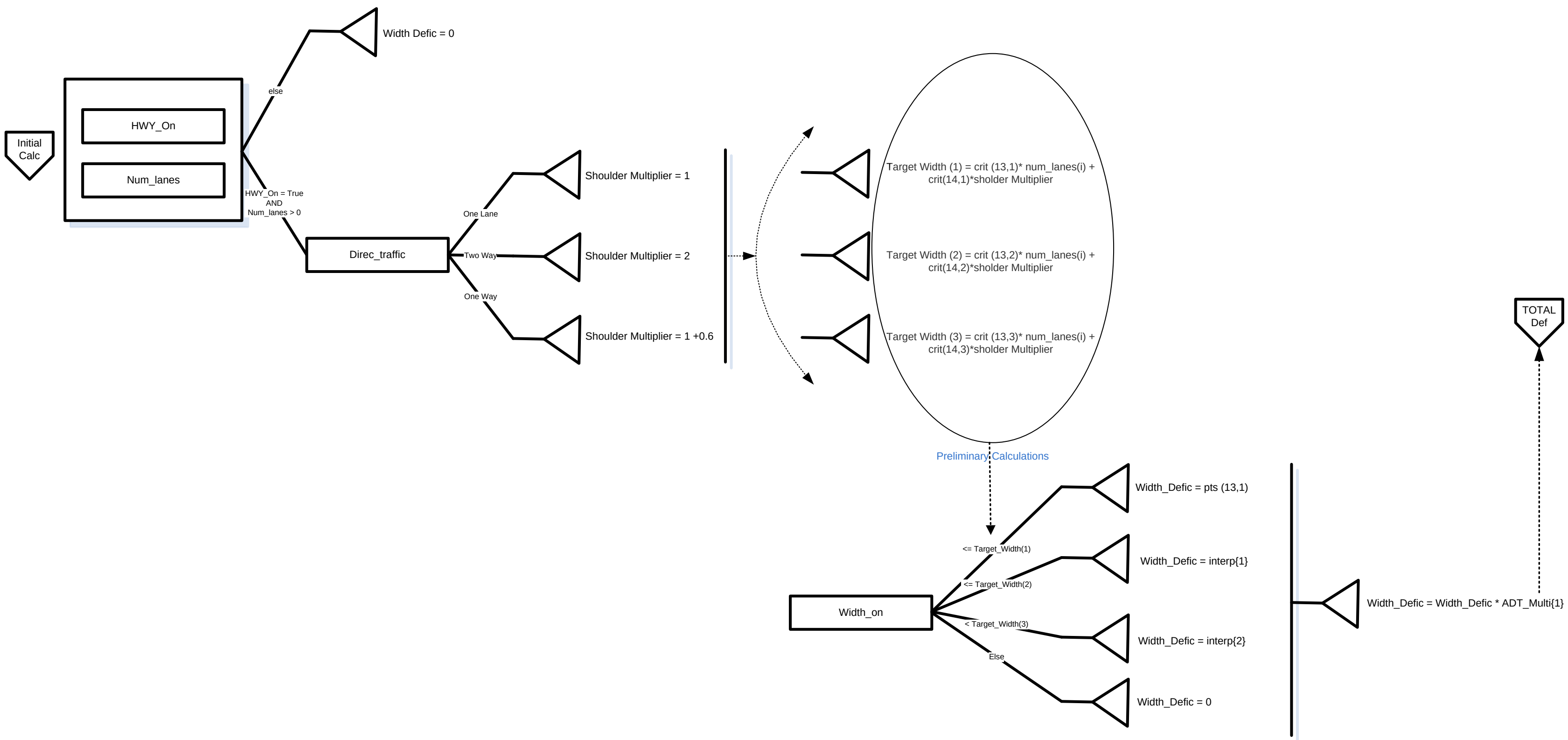


ADT_Mult{1} = {i,9, ADT_Fac, perc_rank_on) where i=Bridge
ADT_Mult{2} = {i,j, ADT_Fac, perc_rank_on) where j = 1 to 8 respectfully
Interp{1} = Interp(Pts(9,1), Pts(9,2), Crit(9,1), Crit(9,2), op_rating(i))
Interp{2} = Interp(Pts(9,2), Pts(9,3), Crit(9,2), Crit(9,3), op_rating(i))

WIDTH DEFICIENCY

```
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
```

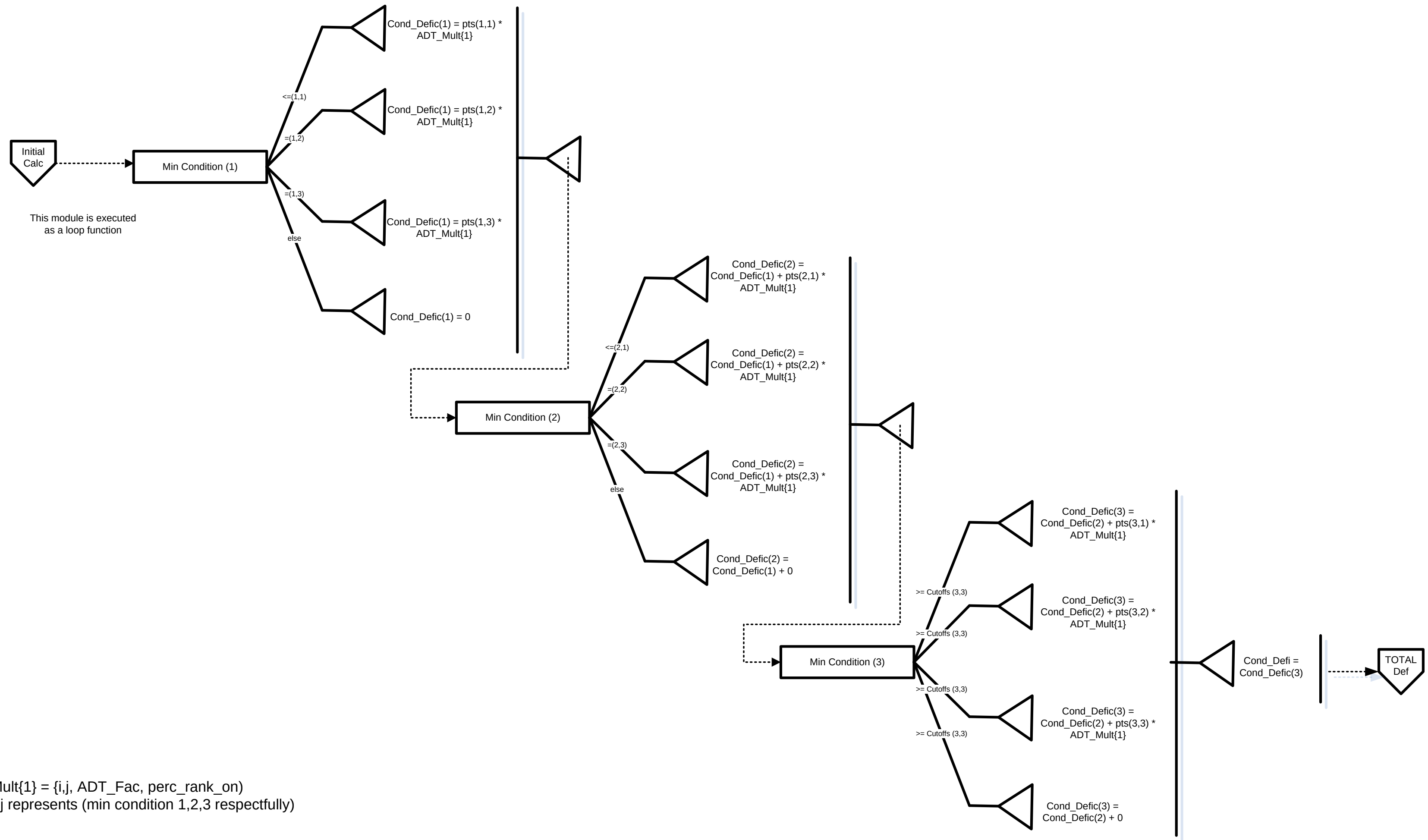


ADT_Mult{1} = {i,13, ADT_Fac, perc_rank_on)
Interp{1} = Interp(Pts(13,1), Pts(13,2), Target_Width(1), Target_Width(2), Width_on(i))
Interp{2} = Interp(Pts(13,2), Pts(13,3), Target_Width(2), Target_Width(3), Width_on(i))

CONDITION DEFICIENCY

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

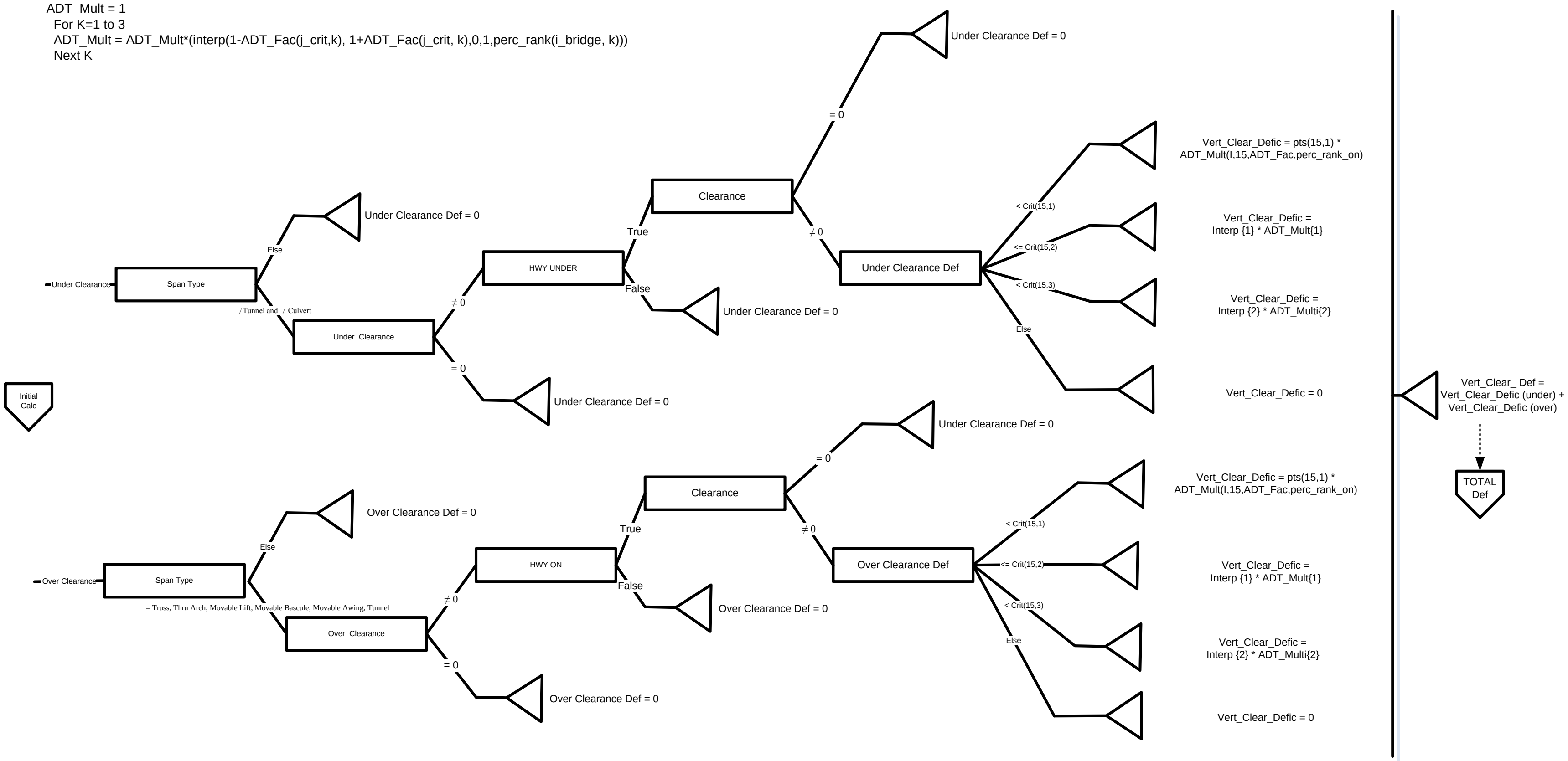


ADT_Mult{1} = {i,j, ADT_Fac, perc_rank_on)
Where j represents (min condition 1,2,3 respectfully)

CLEARANCE DEFICIENCY

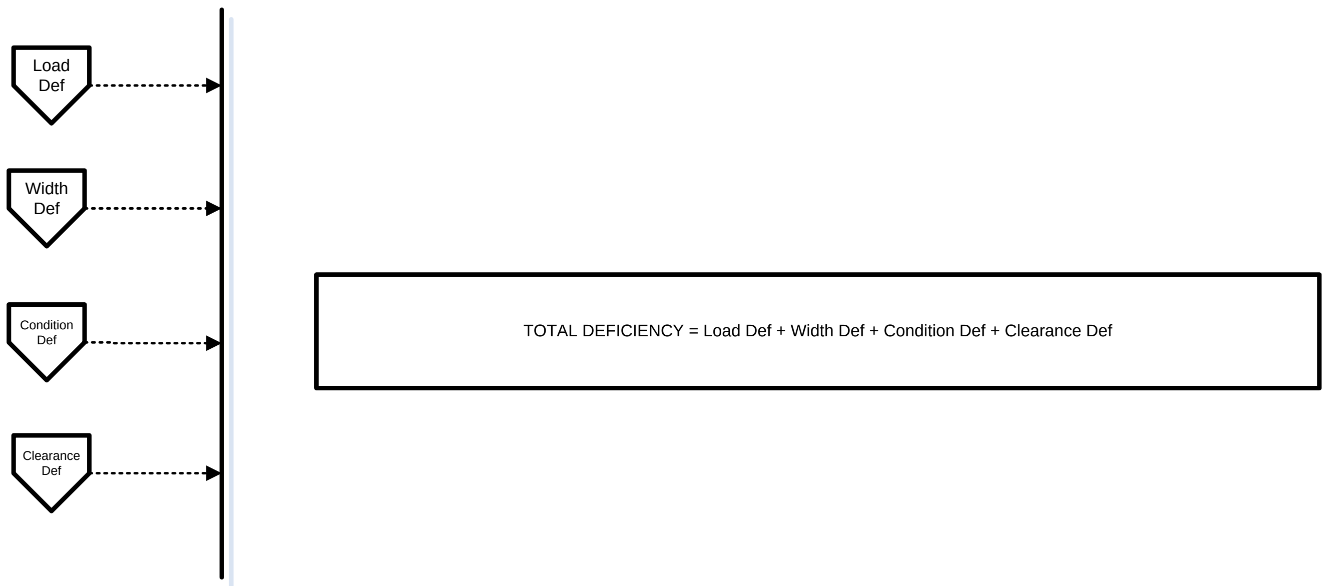
```
Function Interp (y1, y2, x1, x2, x)
Interp = (y2-y1)/(x2-x1) * (x-x1) +y1

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
```



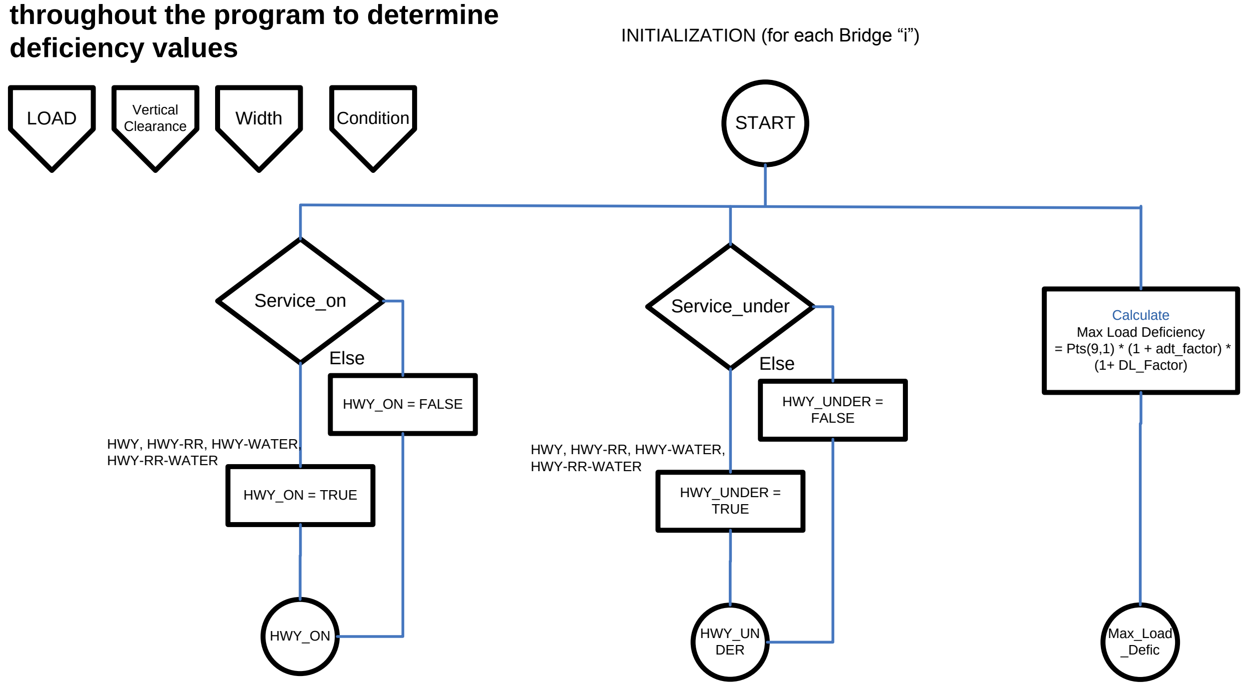
ADT_Mult{1} = {i,15, ADT_Fac, perc_rank_on)
ADT_Mult{2} = {i,15, ADT_Fac, perc_rank_on)
Interp{1} = Interp(Pts(15,1), Pts(15,2), Crit(15,1), Crit(15,2), Overclearance(i))
Interp{2} = Interp(Pts(15,2), Pts(15,3), Crit(15,2), Crit(15,3), Overclearance(i))

TOTAL DEFICIENCY



Appendix B: Flow Chart of Deficiency Algorithm

CALCULATE INITIALIZATION SCORES
These calculations are used throughout the program to determine deficiency values

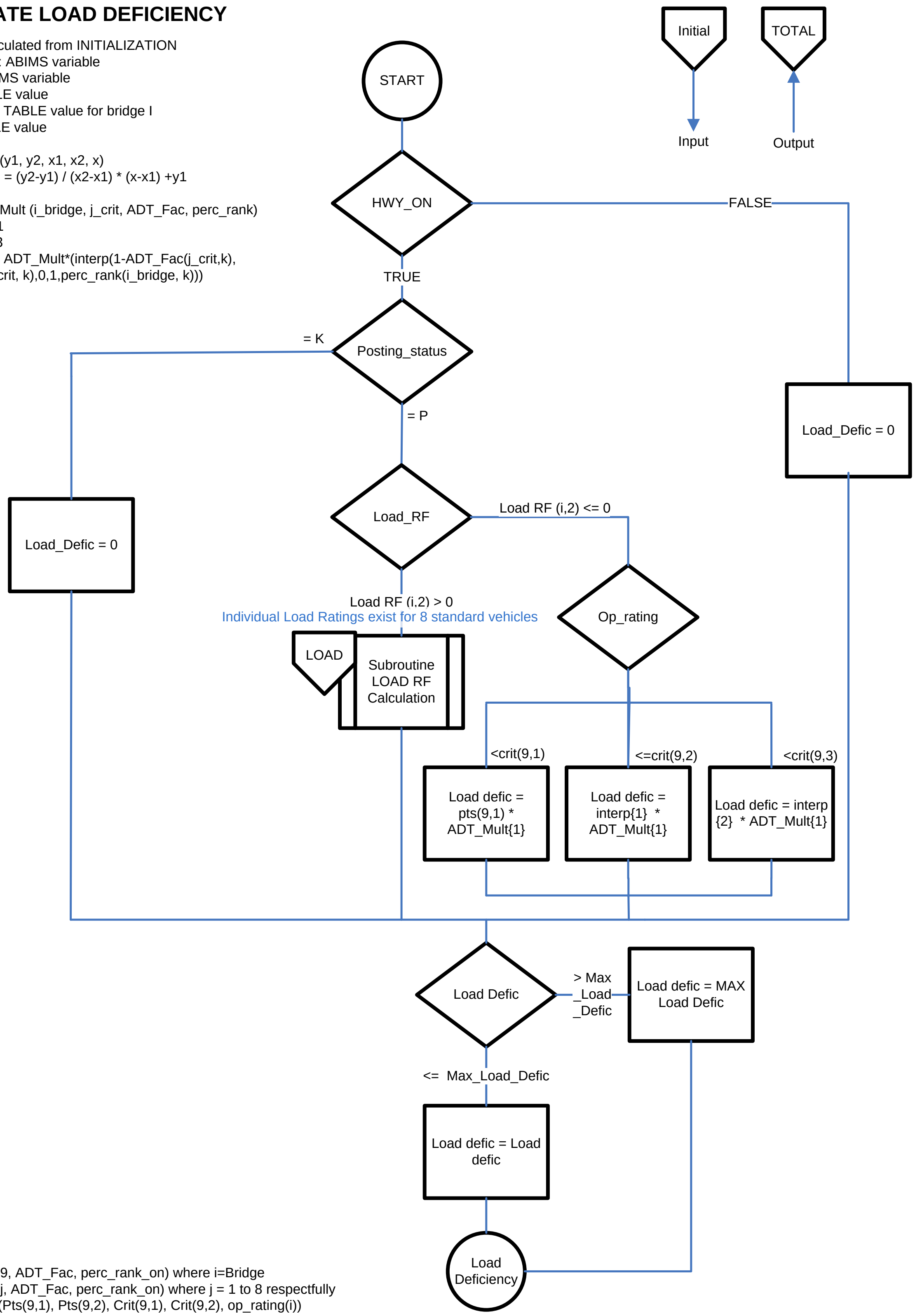


CALCULATE LOAD DEFICIENCY

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

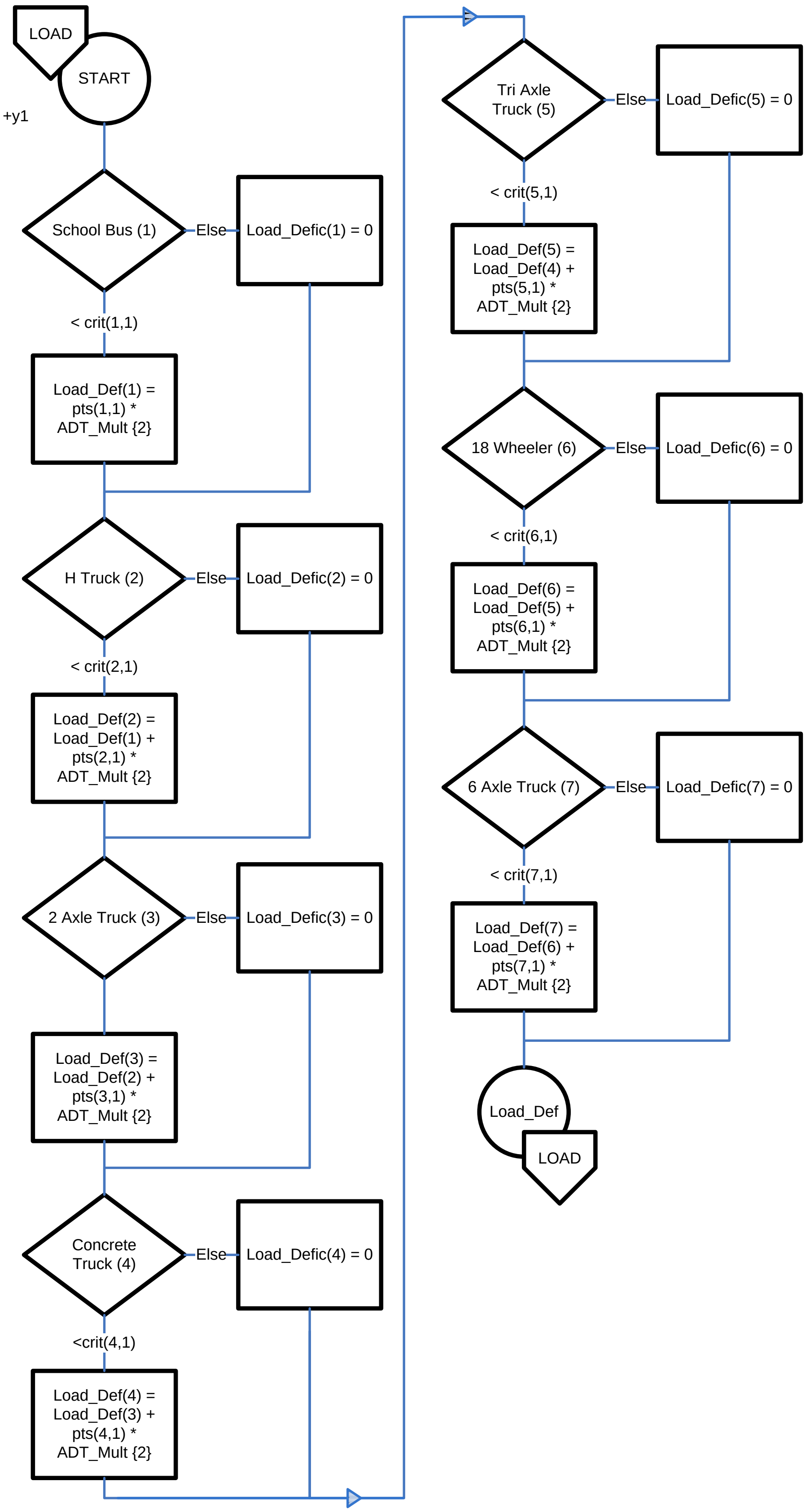


ADT_Mult{1} = {i,9, ADT_Fac, perc_rank_on) where i=Bridge
ADT_Mult{2} = {i,j, ADT_Fac, perc_rank_on) where j = 1 to 8 respectfully
Interp{1} = Interp(Pts(9,1), Pts(9,2), Crit(9,1), Crit(9,2), op_rating(i))
Interp{2} = Interp(Pts(9,2), Pts(9,3), Crit(9,2), Crit(9,3), op_rating(i))

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

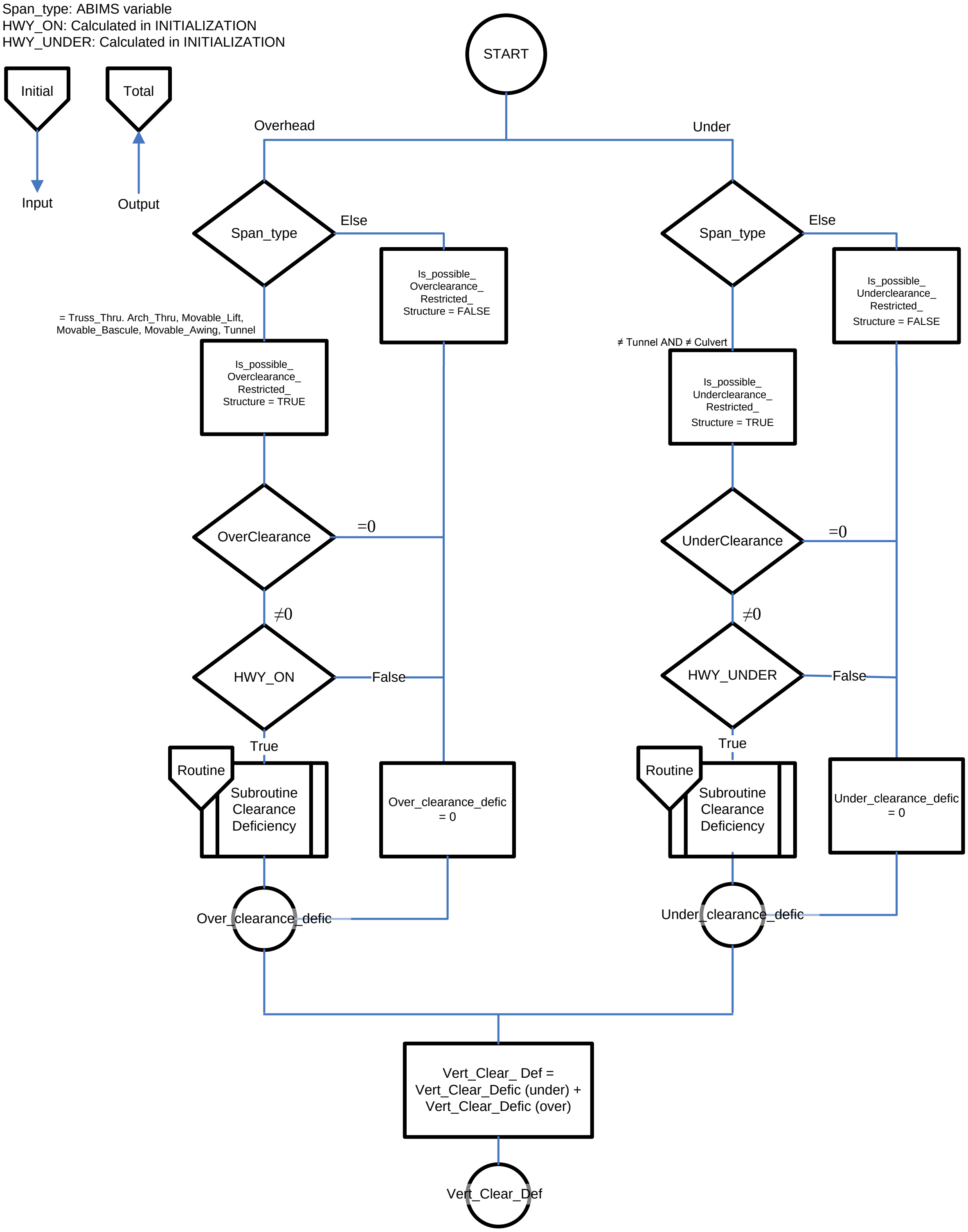
Crit(A,B): TABLE value

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



CALCULATE TOTAL CLEARANCE DEFICIENCY
Calls SUBROUTINE CLEARANCE DEFICIENCY

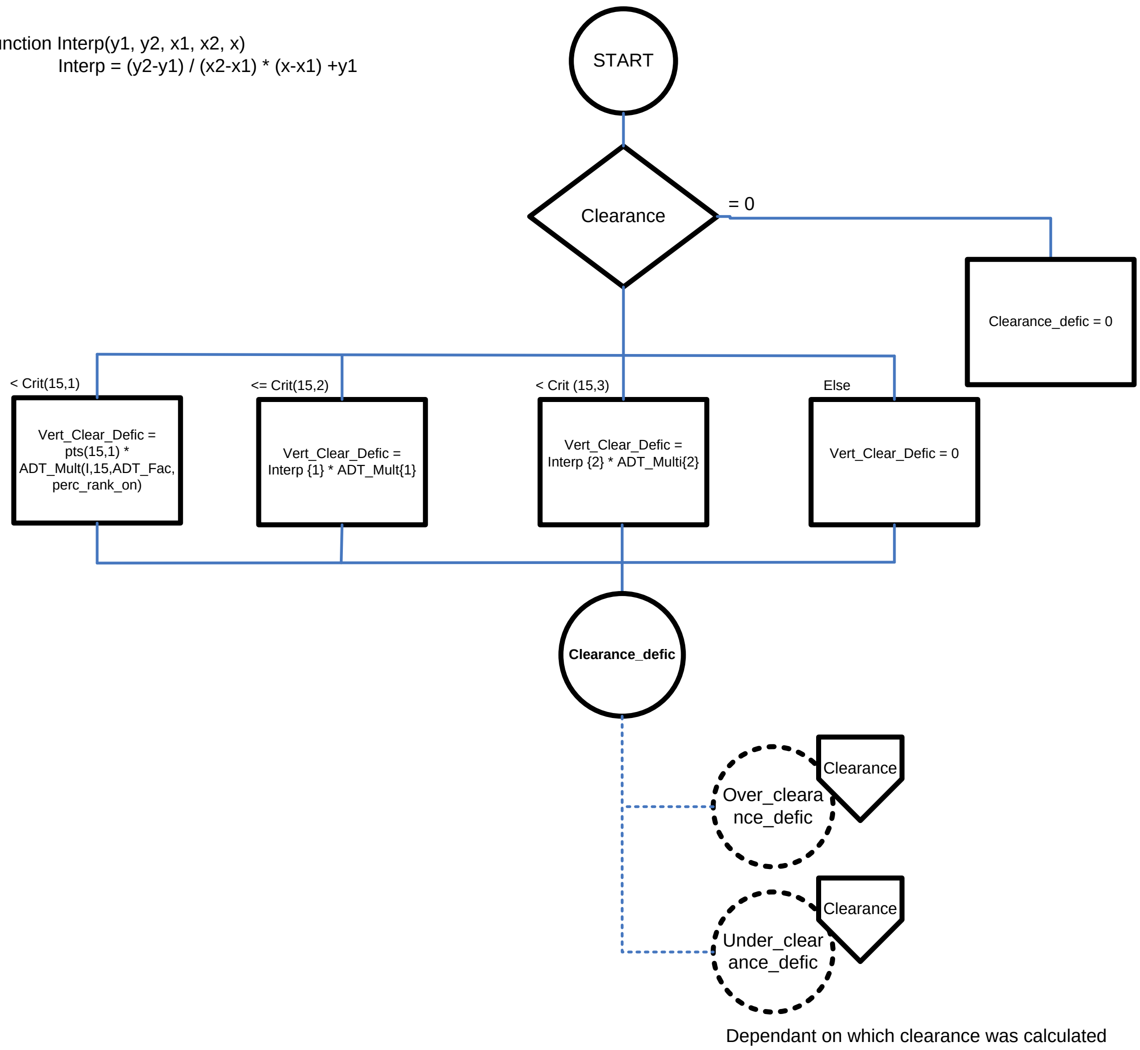
Clearance: ABIMS variable
Span_type: ABIMS variable
HWY_ON: Calculated in INITIALIZATION
HWY_UNDER: Calculated in INITIALIZATION



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



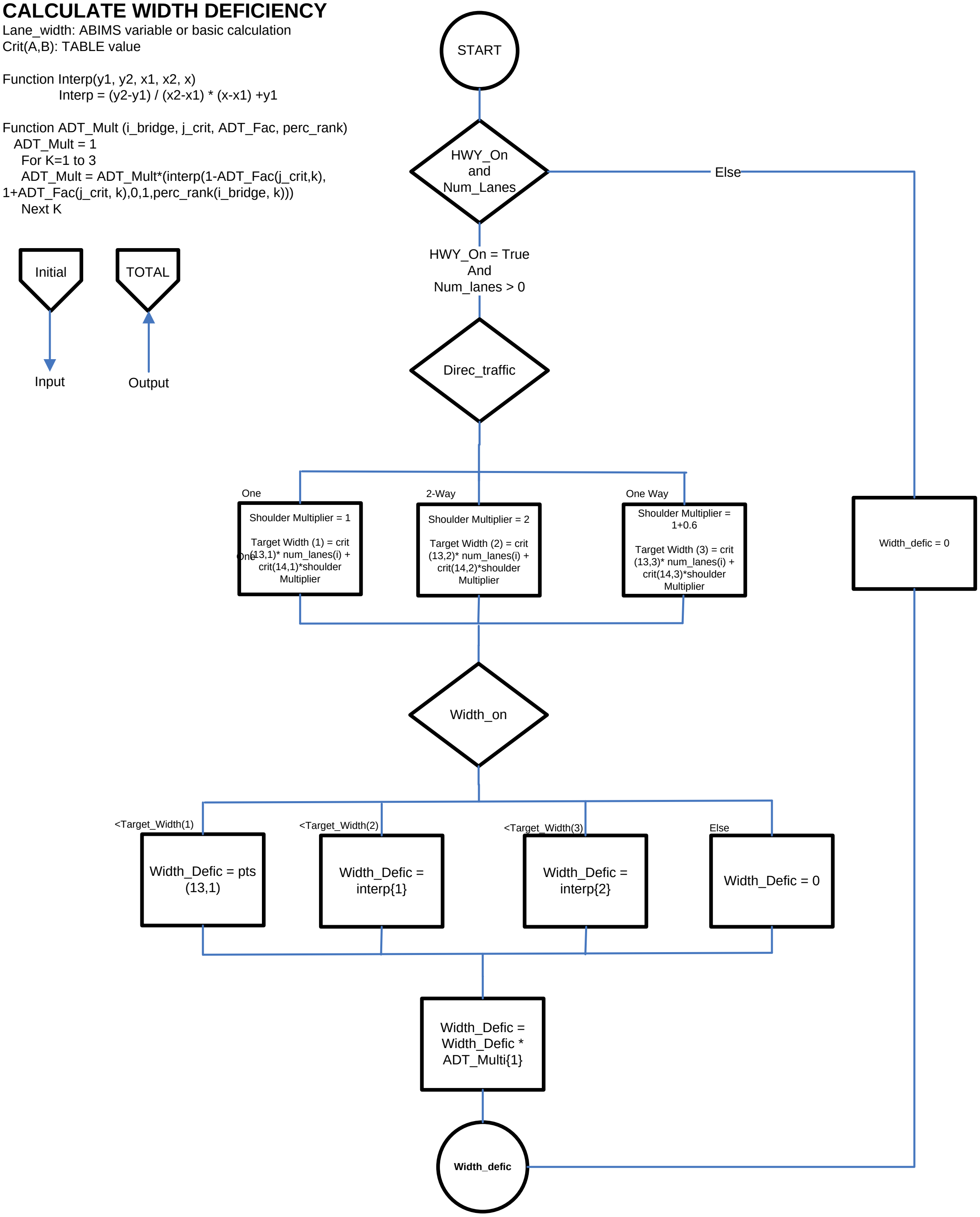
ADT_Mult{1} = {i,15, ADT_Fac, perc_rank_on)
ADT_Mult{2} = {i,15, ADT_Fac, perc_rank_on)
Interp{1} = Interp(Pts(15,1), Pts(15,2), Crit(15,1), Crit(15,2), Overclearance(i))
Interp{2} = Interp(Pts(15,2), Pts(15,3), Crit(15,2), Crit(15,3), Overclearance(i))

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

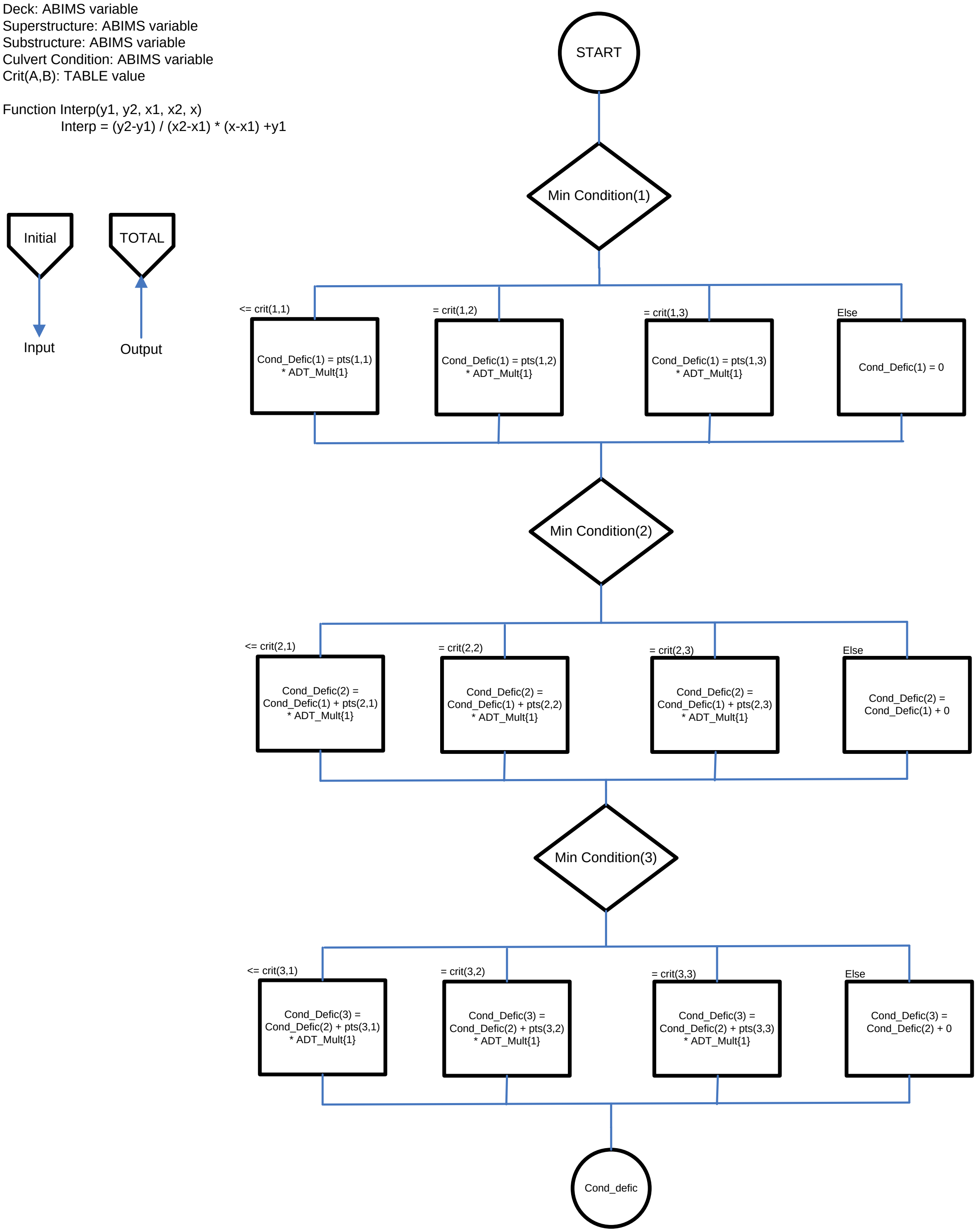


ADT_Mult{1} = {i,13, ADT_Fac, perc_rank_on)
Interp{1} = Interp(Pts(13,1), Pts(13,2), Target_Width(1), Target_Width(2), Width_on(i))
Interp{2} = Interp(Pts(13,2), Pts(13,3), Target_Width(2), Target_Width(3), Width_on(i))

CALCULATE CONDITION DEFICIENCY

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

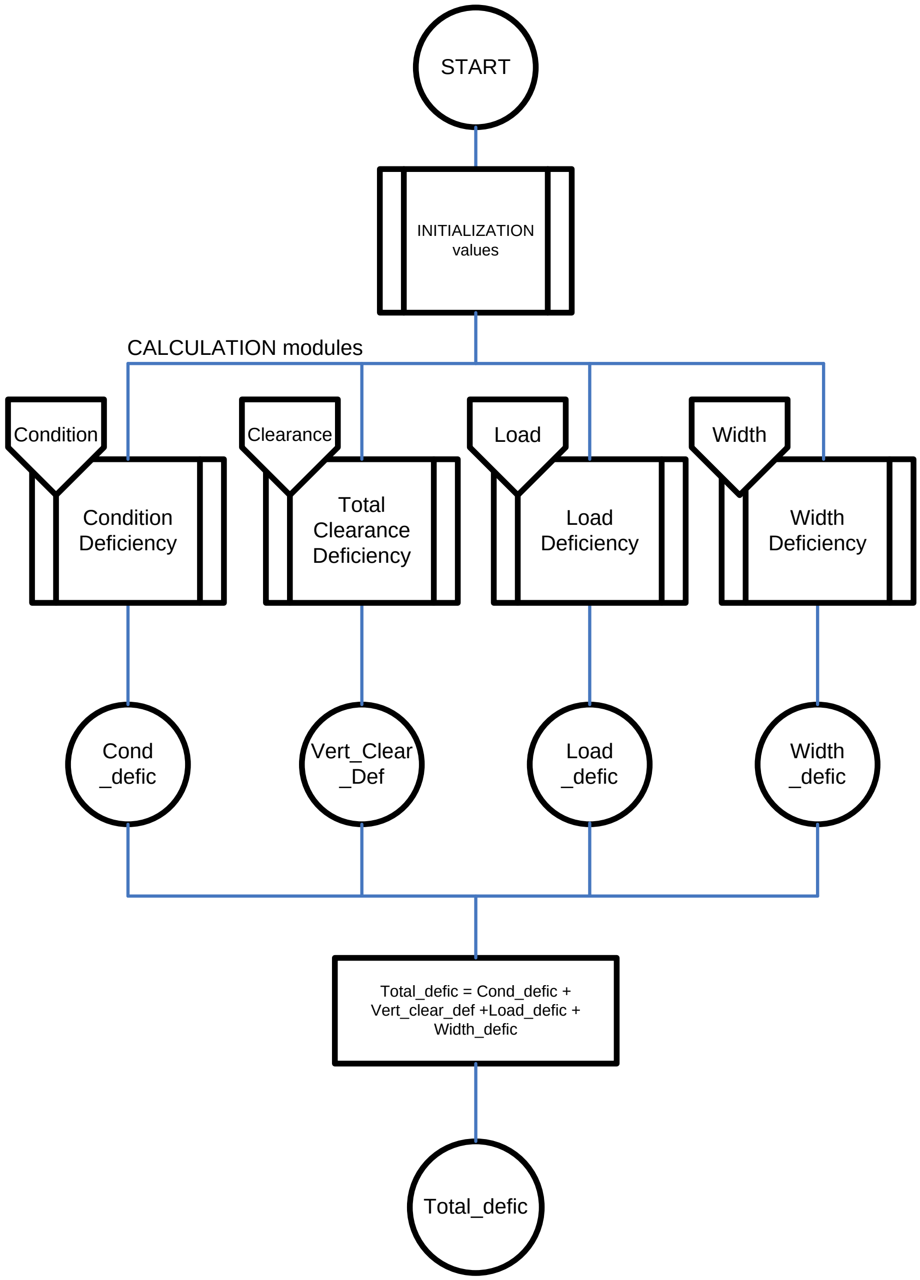
Function Interp(y1, y2, x1, x2, x)
    Interp = (y2-y1) / (x2-x1) * (x-x1) +y1



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



Appendix C: Source Code for Deficiency Algorithm

The deficiency algorithm compares information in the bridge database against the appropriate criteria in the 15-row by 3-column “Criteria” matrix, assigns the points specified in the 15-row by 3-column “Pts” matrix, and multiplies by the factors in the 15-row by 3-column “Factors” matrix. (See Figure C-1.)

- 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.

			Criteria			Pts		Factors ADT	Factors ADTT	Factors DL
SCHOOL_BUS	1	1	0	0	30	0	0	0	0	0.1
H_Truck	2	1	0	0	0	0	0	0	0	0
2_AXLE_TRUCK	3	1	0	0	20	0	0	0	0.3	0.1
CONCRETE_Truck	4	1	0	0	0	0	0	0	0	0.1
HS_Truck	5	1	0	0	0	0	0	0	0	0
TRIAXLE_DUMP_Truck	6	1	0	0	10	0	0	0	0	0.1
18_WHEELER_Truck	7	1	0	0	20	0	0	0	0.3	0.1
6_AXLE_Truck	8	1	0	0	5	0	0	0	0	0.1
Operating Rating (tons)	9	12.5	30	36	40	20	0	0	0.3	0.1
Lowest Condition Rating	10	3	4	5	30	20	0	0.3	0	0.1
2nd Lowest Condition Rating	11	3	4	5	20	10	0	0.3	0	0.1
3rd Lowest Condition Rating	12	3	4	5	10	5	0	0.3	0	0.1
Lane Width	13	10	12	12	20	10	0	0.3	0	0.1
Shoulder Width	14	0	0	10						
Height	15	16	16.3	17	10	8	0	0	0.3	0.1

“ADT_Fac” “Crit” “Pts”

Figure C-1. Matrices used by deficiency algorithm.

The matrix names used in the source code are written at the bottom of the figure.

Source Code:

```
Sub Calc_Defic()

Dim Target_Width(3)

max_Load_Defic = Pts(9, 1) * (1 + adt_factor) * (1 + DL_Factor)
For i = 1 To num_bridges

  Select Case Service_On(i)
    Case "Hwy", "Hwy-RR", "Hwy-Ped", "Overpass", "3rd level Overpass", "4th level Overpass"
      is_highway_on = True
    Case Else
      is_highway_on = False
  End Select
```

```
  Select Case Service_Under(i)
    Case "Hwy", "Hwy-RR", "Hwy-Water", "Hwy-Water-RR"
      is_highway_under = True
    Case Else
      is_highway_under = False
  End Select

'Calc Load Defic
Load_Defic(i) = 0
If is_highway_on And Posting_Status(i) = "P" Then
  If Load_RFs(i, 2) > 0 Then 'If Load Ratings exist for 8 std veh
    For j = 1 To 8
      j_veh = veh_dir(j)
      If Load_RFs(i, j_veh) < Crit(j, 1) Then
        Load_Defic(i) = Load_Defic(i) + Pts(j, 1) * ADT_Mult(i, j, ADT_Fac, perc_rank_on,
ADT_Factor_gt_1)
        Select Case j
          Case Is = 1
            Bridge_Count(i, 6) = 1
          Case Is = 3
            Bridge_Count(i, 7) = 1
          Case Is = 7
            Bridge_Count(i, 8) = 1
          Case Else
            Bridge_Count(i, 9) = 1
        End Select
      End If
    Next j
  Else
    Select Case op_rating(i)
      Case Is < Crit(9, 1)
        Load_Defic(i) = Pts(9, 1)
        Bridge_Count(i, 2) = 1
      Case Is <= Crit(9, 2)
        Load_Defic(i) = interp(Pts(9, 1), Pts(9, 2), Crit(9, 1), Crit(9, 2), op_rating(i))
        Bridge_Count(i, 3) = 1
      Case Is < Crit(9, 3)
        Load_Defic(i) = interp(Pts(9, 2), Pts(9, 3), Crit(9, 2), Crit(9, 3), op_rating(i))
        Bridge_Count(i, 4) = 1
    End Select
    Load_Defic(i) = Load_Defic(i) * ADT_Mult(i, 9, ADT_Fac, perc_rank_on,
ADT_Factor_gt_1)
  End If
  If Load_Defic(i) > max_Load_Defic Then Load_Defic(i) = max_Load_Defic
End If
```

```
'Calc Condition Defic
  min_con = 0
  Cond_Defic(i) = 0
  For j = 10 To 12
    min_con = min_con + 1
    Select Case Min_Conds(i, min_con)
      Case Is <= Crit(j, 1)
        Cond_Defic(i) = Cond_Defic(i) + Pts(j, 1) * ADT_Mult(i, j, ADT_Fac, perc_rank_on,
ADT_Factor_gt_1)
        Bridge_Count(i, 11) = Bridge_Count(i, 11) + 1
      Case Is = Crit(j, 2)
        Cond_Defic(i) = Cond_Defic(i) + Pts(j, 2) * ADT_Mult(i, j, ADT_Fac, perc_rank_on,
ADT_Factor_gt_1)
        Bridge_Count(i, 12) = Bridge_Count(i, 12) + 1
      Case Is = Crit(j, 3)
        Cond_Defic(i) = Cond_Defic(i) + Pts(j, 3) * ADT_Mult(i, j, ADT_Fac, perc_rank_on,
ADT_Factor_gt_1)
        Bridge_Count(i, 13) = Bridge_Count(i, 13) + 1
    End Select
  Next j

'Calc Bridge Width Defic
  Width_Defic(i) = 0
  If is_highway_on And num_lanes(i) > 0 Then
    Select Case Direc_Traffic(i)
      Case Is = "1-lane"
        shoulder_multiplier = 1
      Case Is = "2-way"
        shoulder_multiplier = 2
      Case Is = "1-way"
        shoulder_multiplier = 1 + 0.6
    End Select

    For j = 1 To 3
      Target_Width(j) = Crit(13, j) * num_lanes(i) + Crit(14, j) * shoulder_multiplier
    Next j

    Select Case Width_on(i)
      Case Is = 0  'Error in Database
        Width_Defic(i) = 0
      Case Is <= Target_Width(1)
        Width_Defic(i) = Pts(13, 1)
        Bridge_Count(i, 15) = 1
      Case Is <= Target_Width(2)
```

```
      Width_Defic(i) = interp(Pts(13, 1), Pts(13, 2), Target_Width(1), Target_Width(2),
Width_on(i))
      Bridge_Count(i, 16) = 1
     Case Is < Target_Width(3)
      Width_Defic(i) = interp(Pts(13, 2), Pts(13, 3), Target_Width(2), Target_Width(3),
Width_on(i))
      Bridge_Count(i, 17) = 1
    End Select
    Width_Defic(i) = Width_Defic(i) * ADT_Mult(i, 13, ADT_Fac, perc_rank_on,
ADT_Factor_gt_1)
  End If
  If Direc_Traffic(i) = "1-lane" And num_lanes(i) <> 1 Then Width_Defic(i) = 0 'Error in
Database

'Calc Vertical Clearance Defic
  Vert_Clear_Defic(i) = 0
  'Check OverClearance
  Select Case Span_Type(i)
    Case "Truss -Thru", "Arch -Thru", "Movable -Lift", "Movable -Bascule", "Movable -Swing",
"Tunnel"
     is_poss_overclearance_restricted_structure = True
    Case Else
     is_poss_overclearance_restricted_structure = False
  End Select
  If Overclearance(i) <> 0 And is_highway_on And is_poss_overclearance_restricted_structure
Then
    Select Case Overclearance(i)
     Case Is < Crit(15, 1)
      temp = Pts(15, 1) * ADT_Mult(i, 15, ADT_Fac, perc_rank_on, ADT_Factor_gt_1)
      Bridge_Count(i, 19) = 1
     Case Is <= Crit(15, 2)
      temp = interp(Pts(15, 1), Pts(15, 2), Crit(15, 1), Crit(15, 2), Overclearance(i))
      Bridge_Count(i, 20) = 1
     Case Is < Crit(15, 3)
      temp = interp(Pts(15, 2), Pts(15, 3), Crit(15, 2), Crit(15, 3), Overclearance(i))
      Bridge_Count(i, 21) = 1
     Case Else
      temp = 0
    End Select
    Vert_Clear_Defic(i) = temp * ADT_Mult(i, 15, ADT_Fac, perc_rank_on, ADT_Factor_gt_1)
  End If

  'Check UnderClearance
  If Span_Type(i) <> "Tunnel" And Span_Type(i) <> "Culvert" Then
    is_poss_underclearance_restricted_structure = True
  Else
```

```
    is_poss_underclearance_restricted_structure = False
  End If
  If Underclearance(i) <> 0 And is_highway_under And
is_poss_underclearance_restricted_structure Then
    Select Case Underclearance(i)
      Case Is < Crit(15, 1)
        temp = Pts(15, 1) * ADT_Mult(i, 15, ADT_Fac, perc_rank_on, ADT_Factor_gt_1)
        Bridge_Count(i, 19) = Bridge_Count(i, 18) + 1
      Case Is <= Crit(15, 2)
        temp = interp(Pts(15, 1), Pts(15, 2), Crit(15, 1), Crit(15, 2), Underclearance(i))
        Bridge_Count(i, 20) = Bridge_Count(i, 19) + 1
      Case Is < Crit(15, 3)
        temp = interp(Pts(15, 2), Pts(15, 3), Crit(15, 2), Crit(15, 3), Underclearance(i))
        Bridge_Count(i, 21) = Bridge_Count(i, 20) + 1
      Case Else
        temp = 0
    End Select
    Vert_Clear_Defic(i) = Vert_Clear_Defic(i) + temp * ADT_Mult(i, 15, ADT_Fac,
perc_rank_under, ADT_Factor_gt_1)
  End If

 Total_Defic(i).Value = Load_Defic(i) + Cond_Defic(i) + Width_Defic(i) + Vert_Clear_Defic(i)

Next i

'Set closed bridges to max defic
If Range("Set_Closed_to_Max_Defic") Then
  max_defic = WorksheetFunction.Max(Total_Defic)
  For i = 1 To num_bridges
    If Posting_Status(i) = "K" Then
      Bridge_Count(i, 1) = 1
      Select Case Service_On(i)
        Case "Hwy", "Hwy-RR", "Hwy-Ped", "Overpass", "3rd level Overpass", "4th level
Overpass"
          Total_Defic(i) = max_defic
      End Select
    End If
  Next i
End If

col_num = WorksheetFunction.Match("Total_Defic", Range("Headings"), 0)
All_Defic_Data.sort , Key1:=All_Defic_Data.Columns(col_num), Order1:=xlDescending

'Find last bridge with deficiencies
i = num_bridges
Do While Total_Defic(i) = 0
```

```
  i = i - 1
Loop
num_defic_bridges.Value = i

For i = 1 To num_defic_bridges
  Rank(i).Value = i
Next i

End Sub
```

```
Function ADT_Mult(i_bridge, j_Crit, ADT_Fac, perc_rank, ADT_Factor_gt_1)

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

If ADT_Factor_gt_1 Then
  If ADT_Mult < 1 Then ADT_Mult = 1
End If

End Function
```

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