AN ANALYSIS OF BRIDGE INSPECTION DATA

Progress Report on

A LEVEL OF SERVICE SYSTEM FOR BRIDGE EVALUATION

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A LEVEL OF SERVICE SYSTEM
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ABSTRACT

Data collected during Federally mandated bridge inspections is a valuable resource. Evaluations based upon the data influence levels of Federal funding and determine types of funding uses. Nevertheless, the states and other owners have significant flexibility in selection of bridges for replacement and rehabilitation. Methods are needed for analyzing the data to facilitate bridge management functions and long range planning related to replacement, rehabilitation and maintenance.

This paper reports research efforts to develop methods to enhance utilization of North Carolina inspection data by evaluating bridges based upon deficiency as related to acceptable and desirable levels of service. Methods of prioritization are also introduced. The long range goal of the research is to develop a maintenance, rehabilitation and replacement priority system with the capability of estimating future funding needs.

TABLE OF CONTENTS

I. INTRODUCTION

The establishment of a Federally mandated system for bridge inspection, evaluation and reporting (Ref. 1) has provided the states with a valuable data resource. Regularly updated individual inspection reports and especially the computerized Structure Inventory and Appraisal data file have been essential for rapid evaluation and identification of bridges.

Three summary evaluations are made for each bridge under the Federal system. The Sufficiency Rating, ranging from 0 to 100 points, is calculated; the bridge is classified as Structurally Deficient or not, and as Functionally Obsolete or not. Depending upon the Sufficiency Rating a bridge may be eligible for Federal funding for replacement or rehabilitation. However, within broad ranges of sufficiency rating (0 - 50 for replacement or rehabilitation and 50 - 80 for rehabilitation) the states may prioritize the order of funding.

Thus, the states are faced with two related problems. First, although the data base is available and the data can be tabulated and summarized in many ways using the National Bridge Inventory Report Generator Program (Ref. 2), there is a need for in depth analysis of the data over a period of time to provide long range bridge management information. Any one inspection cycle provides a snapshot but not a history nor a trend. Second, methods are needed for prioritizing bridges for replacement, rehabilitation and maintenance.

There are both short term and long term possibilities. In the long term, trends accumulated from analysis of the data base over several cycles of inspection will assist in optimizing selection of bridges for maintenance, rehabilitation and replacement. In the short term, less refinement is possible; nevertheless, prioritization must be based upon the degree to which a bridge is deficient in meeting public needs.

With the support of the North Carolina Department of Transportation, a study has been undertaken with the following objectives.

1. Develop methods to enhance inspection data utilization in the management of bridge maintenance, rehabilitation and replacement.
2. Establish a Level of Service system which can serve as a basis for evaluating the adequacy of North Carolina bridges in serving public needs.
3. Prioritize bridges in order of need based upon Level of Service deficiency.
4. Evaluate the present cost of replacement or rehabilitation to achieve the needed levels of service.
5. Determine the impact of maintenance and deferred maintenance by task.
6. Develop a least cost maintenance, rehabilitation and replacement priority system with the capability of estimating future funding needs.

This paper represents a progress report on the results of efforts to achieve the above objectives. Tasks incorporating the first three objectives have been completed. The approaches being used are presented at this time for the benefit of other bridge owners faced with similar problems.

2. NATURE OF NORTH CAROLINA BRIDGE PROBLEMS

In North Carolina there are approximately 17,300 bridges. Over 16,800 of these or 97% are state maintained bridges compared to 46% state maintained nationwide. Thus, unlike most state maintained inventories which are dominated by interstate, arterial and collector system bridges, the NCDOT maintained inventory is 56% local system bridges serving low traffic volumes. Almost 40% of the total inventory is located on routes with an average daily traffic volume (ADT) of less than 250 vehicles.

Approximately 65% of the bridges in North Carolina are classified as structurally deficient or functionally obsolete as detailed in Table 2.1. This relatively high percentage often evokes a public assumption of significant deterioration, but analysis of the inspection data reveals a clearer picture. Figure 2.1 shows the frequency of condition ratings for the deck, superstructure and substructure. A rating of 4 (indicating marginal condition with potential for minor rehabilitation) or less on any of these items would cause a bridge to be classified as structurally deficient. However, note that virtually all the bridges are in good to fair condition indicating that they have generally been well maintained.

Thus, the high percentage of structurally deficient bridges is not due to condition as related to maintenance versus deterioration. As shown in Tabel 2.2, the principal cause for classification as structurally deficient is the rating for Structural Condition. As shown in Tabel 2.3, the principal causes for classification as functionally obsolete are Structural Condition and Deck Geometry. Some bridges are classified as deficient or obsolete for more than a single cause.

Table 2.1 Classification of N. C. Bridges

Classification	No. Of Bridges	%
Structurally Deficient	5664	34
Functionally Obsolete	5333	31
Neither	5792	35
Total	16789	100

Table 2.2 Items Causing Structural Deficient

Item	Number of Bridges
Structural Condition <= 2	5044
Deck Condition <= 4	569
Superstructure Condition <= 4	458
Substructure Condition <= 4	838
Waterway Appraisal <= 2	14
Total (some include multiple items)	5664

Table 2.3 Items Causing Functionally Obsolete

Item	Number of Bridges
Structural Condition <= 3	3151
Deck Geometry <= 3	3009
Approach Alignment <= 3	1188
Underclearances <= 3	1163
Waterway Adequacy <= 3	45
Total (many include multiple items)	5333

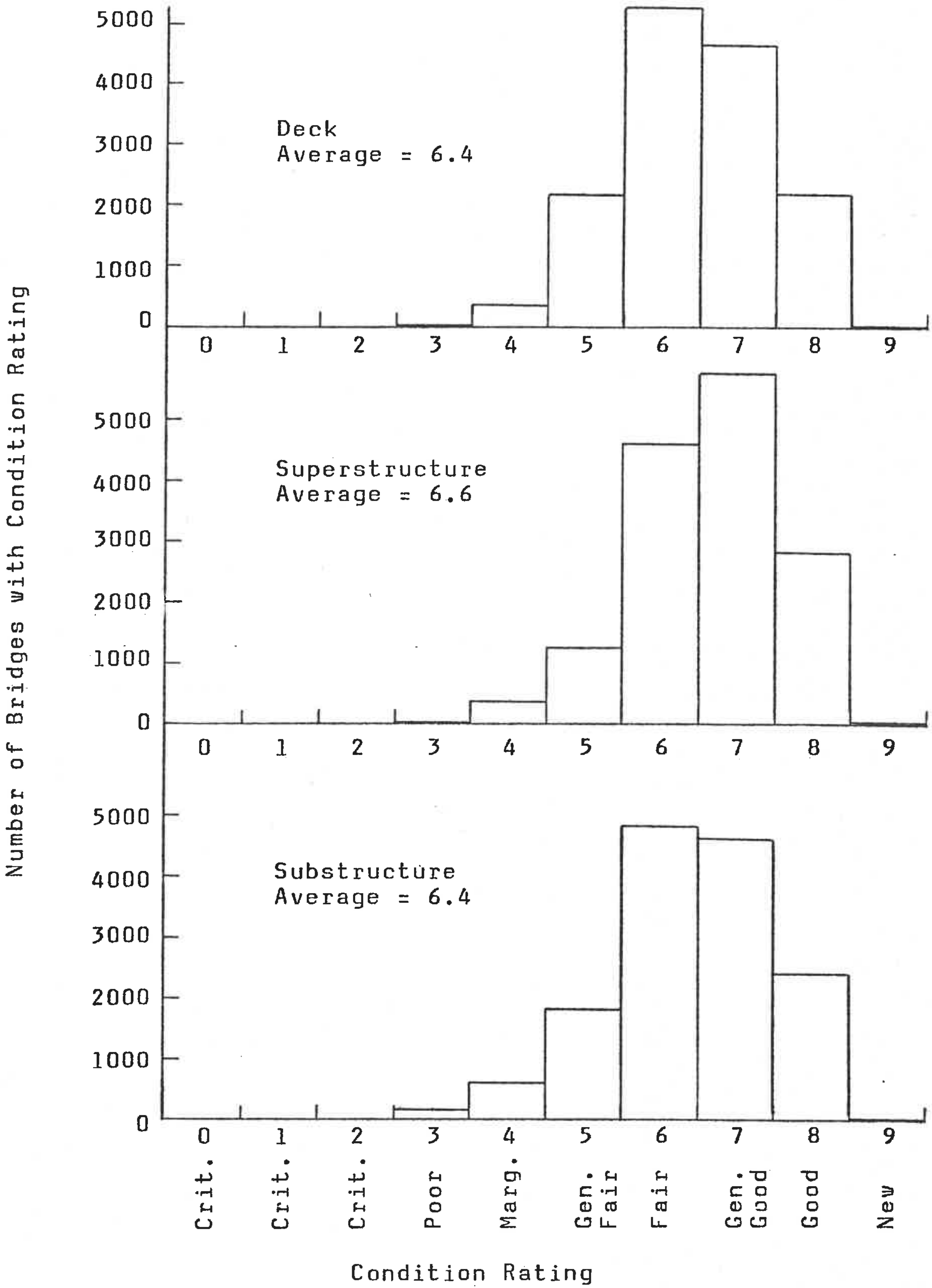

Figure 2.1 Frequency of Deck, Superstructure and Substructure Condition Ratings

Structural Condition is not a qualitative evaluation of bridge condition, rather it is a quantitative evaluation of bridge load capacity. For many years, North Carolina was a state with very limited resources and yet a large geographical area. In order to provide access to rural areas, limited funds were stretched by constructing relatively narrow and low load capacity (HS-10 & HS-15) bridges on low ADT roads. Approximately 3600 of these bridges have timber superstructures and many others have timber piles which further reduce the condition rating. Thus, although many have been maintained in good condition, the Structural Condition rating, is often 1, 2 or 3, causing the bridge to be deficient or obsolete.

The distribution of posted bridges versus ADT volume is shown in Table 2.4. While any posting due to load capacity is undesirable, it must also be recognized that low load capacities on high ADT routes (the lower left triangle of the matrix) is least acceptable. Since determination of Sufficiency Rating places a heavy weighting on Adjusted Inventory Tonnage, Structural Condition and Width, the distribution (Table 2.5) of Sufficiency Ratings versus ADT volume is similar.

Under Federal criteria, a large number of North Carolina bridges are eligible for replacement or rehabilitation funding. However, prioritizing strictly on the basis of Sufficiency Rating does not place adequate emphasis on appropriate service in proportion to public need. The Sufficiency Rating places little emphasis on volume of traffic, detour length and level of service needed on various functional systems such as arterials, collectors and local systems. An additional system of evaluation which more directly considers these factors is needed, especially where the maintenance condition of the bridges

Table 2.4 ADT Versus Single Vehicle Posting

ADT	No. with Single Vehicle Posting (*) Between 3-8	9-15	16-24	25-33	NP	Total
Under 250	327	2002	2354	668	1220	6571
250-499	96	647	626	388	711	2468
500-999	55	380	443	343	802	2023
1000-1999	24	160	223	222	869	1498
2000-3999	6	47	82	128	1035	1298
Over 3999	4	26	56	136	2709	2931
Total	512	3262	3784	1885	7346	16789

* Posting in tons based on Operating Rating

Table 2.5 ADT versus Sufficiency Rating

ADT	No. with Sufficiency Rating Between 0-25	25-50	50-80	80-100	Total
Under 250	399	2832	2532	808	6571
250-499	242	1077	772	377	2468
500-999	183	736	676	428	2023
1000-1999	123	383	546	446	1498
2000-3999	57	176	462	603	1298
Over 3999	65	252	1166	1448	2931
Total	1069	5456	6154	4110	16789

is fair to good and the estimated bridge remaining life is relatively long. In order to meet this need, a Level of Service system has been developed for evaluation and prioritization of bridges on the basis of level of service deficiency.

3. BRIDGE LEVEL OF SERVICE

Although it might be ideal to have all existing bridges meet North Carolina Bridge Policy (Ref. 3) requirements for new bridges, it is recognized that this is not financially possible. Thus, a method of determining an appropriate Level of Service for each bridge is established herein.

There are many characteristics that can contribute to making a bridge safe, functional and beneficial to the public. However, three characteristics most directly contribute to these needs:

1. Load Capacity
2. Clear Bridge Deck Width
3. Vertical Roadway Underclearance and Overclearance

The level of service goal for each of these characteristics will vary depending upon the volume of traffic and the functional classification of the roadway. Furthermore, the goals can be set at an "acceptable" low level, at a "desirable" higher level or at an intermediate level between these two.

Level of Service goals, acceptable and desirable, are defined in Tables 3.1, 3.2, and 3.3 for capacity, width and vertical clearance respectively.

3.1 Functional Classifications

North Carolina highway segments between intersections are classified according to the functional service provided by the route in meeting statewide transportation needs. Bridges are classified in the same functional system as the route carried by the bridge. The principal functional classifications are as follows:

1. Interstate and Arterial Systems - Provide moderate to high volume highways for travel between major points. These highways are primarily for through traffic, usually on a continuous route, and are generally the top 10% of the total highway system based on relative importance for statewide travel.

2. Collector System - Provides primarily intracounty service with shorter travel distances and generally more moderate speeds. These routes provide service to county seats and towns not on the arterial system. Routes which carry traffic from local roads to arterials are collectors.

3. Local System - Provides access to farms, residences, businesses, or other abutting properties. Traffic volume is low and local in nature.

The systems are further subdivided in some cases. For example, collectors are divided into major collectors and minor collectors.

3.2 Acceptable Goals

The "acceptable" load capacity goals seek to provide a safe and functional level of strength to serve most vehicles expected on the route being served. The minimum acceptable level is that which would accommodate essential vehicles such as passenger cars, school buses, fire trucks, residential garbage trucks, heating oil home delivery trucks and two axle electrical utility line trucks on all routes.

All normal passenger cars can be accommodated within the 3 ton capacity required for an open bridge. A survey was conducted by the NCDOT Bridge Maintenance Unit to determine the weights of essential service vehicles. Inquiries to the State Department of Public Instruction indicate that the weight of loaded school buses ranges from 6 tons to a maximum of 12 tons. Fire trucks for the City of Raleigh weigh approximately 16 tons. Special permits are obtained for those in the 18 to 20 ton range. Wake County rural fire trucks are limited to 15 tons and most do not exceed 11 to 12 tons. Residential garbage trucks in Raleigh and Wake County are all two axle vehicles limited to a legal weight of 15.75 tons. Commercial garbage trucks are often 3 axle or tandum vehicles with 22.5, 25 or 33.6 ton legal limits. Carolina Power & Light Co. line trucks generally weigh 13 tons, although there are a limited number of 18 ton tandum axle trucks.

Furthermore, operation of a vehicle weighing more than 15 tons requires a chauffeurs' license which would imply a better operator understanding of vehicle weight and posting requirements. Based upon the above factors, a minimum acceptable load capacity goal of 16 tons was established, as shown in Table 3.1. This level will serve all two axle trucks and two and three axle buses. Higher capacities are needed for major collectors, arterials and interstates to serve commerce and industry with a minimum of detour. The major collector goal of 25 tons was selected to serve the needs of all 3 axle trucks, which would include many concrete trucks and logging trucks.

Clear bridge deck width goals are intended to provide reasonable safety. Narrow bridges contribute to both single and multiple vehicle collisions as well as accidents involving pedestrians. Width needs depend upon the volume of traffic (ADT) and the roadway functional classification (as an indication of traffic content and speed). The acceptable goals shown in Table 3.2 generally correspond to bridge policy for existing bridges to remain in place when the approach roadway is reconstructed. However, a width of 26 ft. rather than 28 ft. was accepted for local and collector systems with ADT over 4000 vehicles. Also, the current year ADT is used for the evaluation of acceptability rather than a design year ADT. Table 3.2 presents width goals for two lane bridges. For bridges with other than two lanes, the width goals are calculated from lane and shoulder dimensions given in Table 3.2A.

Vertical roadway underclearance goals affect only those bridges which span over another roadway. Vertical roadway overclearance goals affect only those bridges such as trusses which have overhead obstructions. The benefits of adequate vertical clearance are related to reducing detours of vehicles serving commerce and industry and detours of certain farm equipment as well as reducing collision damage. The acceptable goals shown in Table 3.3 correspond to the minimum vertical clearance not requiring posting. At 14.0 ft., this is slightly higher than the legal maximum height of 13.5 ft. in order to allow for vehicle bounce and resurfacing between inspections.

3.3 Desirable Goals

The "desirable" goals for load capacity, deck width and vertical clearance generally correspond to North Carolina Bridge Policy for new bridge construction. Current ADT is used in the evaluation rather than design year ADT. However, the bridge width goals have been adjusted assuming that design year ADT would be approximately double current ADT.

Table 3.1 Bridge Capacity Goals

Road Over Functional Classification	Single Vehicle Capacity	
	Acceptable	Desirable
Interstate & Arterial	NP	NP
Major Collector	25 Tons	NP
Minor Collector	16 Tons	NP
Local	16 Tons	NP

NP = Not Posted (capacity = 33.6 Tons for single vehicles)

Table 3.2 Clear Bridge Deck Width Goals for Two Lane Routes

Road Over Functional Classification	Current ADT	Clear Width (Feet)	
		Acceptable	Desirable
Interstate & Arterial	ADT ≤ 800	22	32
	801 - 2000	24	36
	2001 - 4000	26	40
	Over 4000	28	40
Major & Minor Collectors	ADT ≤ 800	20	24
	801 - 2000	22	28
	2001 - 4000	24	30
	Over - 4000	26	30
Local	ADT ≤ 800	20	24
	801 - 2000	22	28
	2001 - 4000	24	30
	Over 4000	26	30

For bridges with more than two lanes see Table 3.2 A. Width = No. of lanes (lane width) + 2(shoulder width).

Table 3.2A Clear Bridge Deck Width Goals (Lane & Shoulder)

Road Over Functional Classification	Current ADT	Acceptable		Desirable	
		Lane	Shoulder	Lane	Shoulder
Interstate & Arterial	ADT ≤ 800	10	1	12	4
	801 - 2000	10	2	12	6
	2001 - 4000	11	2	12	8
	Over - 4000	11	3	12	8
Major & Minor Collectors	ADT ≤ 800	9	1	10	2
	801 - 2000	9	2	11	3
	2001 - 4000	10	2	12	3
	Over 4000	10	3	12	3
Local	ADT ≤ 800	9	1	10	2
	801 - 2000	9	2	11	3
	2001 - 4000	10	2	12	3
	Over 4000	10	3	12	3

Table 3.3 Bridge Vertical Underclearance Goals

Road Under Functional Classification	Underclearance (Feet)	
	Acceptable	Desirable
Interstate & Arterial	14.0	16.5
Major & Minor Collectors	14.0	15.0
Local	14.0	15.0

Bridge vertical overclearance goals for the road over functional classification shall be the same as the above values.

4. PRIORITIZATION BASED UPON NEED

The method of prioritization involves calculation of Deficiency Points. The four major areas of deficiency to be evaluated are:

	Weighting
1. Single Vehicle Load Capacity	WC = 70
2. Clear Bridge Deck Width	WW = 12
3. Vertical Roadway Under/overclearance	WV = 12
4. Estimated Remaining Life	WL = 6

Within the above areas, additional consideration is given to volume of traffic and length of detour.

The deficiency magnitude expressed in Deficiency Points, DP, (the larger DP, the more deficient the bridge) is given by

$$DP = CP + WP + VP + LP \qquad \text{(Eq.4.1)}$$

where CP, WP, VP, and LP are priority points accumulated from evaluation of capacity, width, vertical clearance and remaining life respectively. The method for determining each of these point parameters follows.

4.1 Single Vehicle Load Capacity Priority (CP)

Calculation of capacity priority considers:

CG = Capacity Goal, Tons (Table 3.1)

SV = Single Vehicle Posting, Tons

ADTO = Average Daily Traffic of Over Route

DL = Detour Length, Miles

WC = Capacity Weighting

User costs related to the load capacity of a bridge are generated from time lost and extra mileage accumulated during detour around a posted bridge. These costs increase essentially linearly with Capacity Deficiency (CG-SV), Average Daily Traffic and Detour Length. Thus, ADT and Detour

Length are included in a linear factor, KD, in the following analysis. However, some public costs are not linear. A posted bridge is more likely to be damaged by overload. While the overload may occur with higher frequency on a high ADT route, a single overload on a low ADT route produces similar damage. Furthermore, there is a need to provide basic service that is not directly proportional to ADT. Thus, a second non-linear factor, KA, increases with ADT but provides somewhat extra consideration for low ADT bridges.

The priority is calculated as follows:

$$CP = WC \times \left(\frac{CG - SV}{10}\right) \times (0.6KA + 0.4KD) \qquad \text{(Eq. 4.2)}$$

where

$$KA = \frac{(ADT)^{0.30}}{12} \qquad \text{(Eq. 4.3)}$$

$$KD = \frac{DL}{20} \times \left(\frac{ADTO}{4000}\right) \qquad \text{(Eq. 4.4)}$$

and the priority is limited to the range $0 \leq CP \leq WC$. The relationships expressed by Equation 4.2 are shown in Figure 4.1.

4.2 Clear Bridge Deck Width Priority (WP)

Calculation of width priority considers:

WG = Width Goal, Feet (Tables 3.2 and 3.2A)

CDW = Present Clear Deck Width, Feet

ADTO = Average Daily Traffic of Over Route

WW = Width Weighting

User costs related to bridge width are associated with accidents. Narrow bridges contribute to single vehicle collisions involving bridge elements or pedestrians and to multiple vehicle collisions involving approaching or passing vehicles. Direct user costs include loss of life, injuries

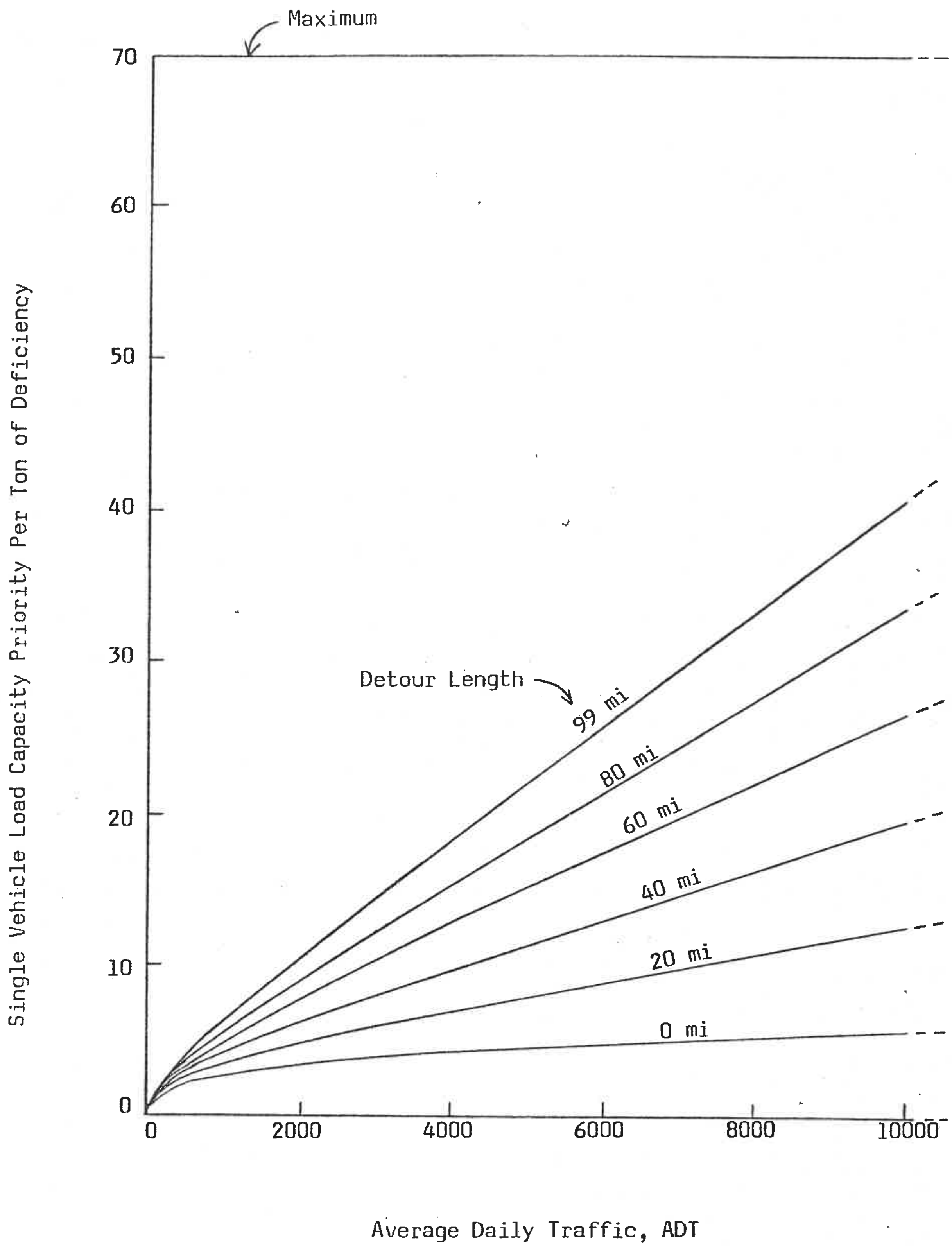

Figure 4.1 Capacity Priority Per Ton Versus ADT and Detour

and vehicle damage. Public costs include increased insurance premiums and bridge damage repair. The expected numbers of accidents and resulting costs would increase as a function of Width Deficiency (WG-CDW) and Average Daily Traffic. The relationship is essentially linear for both parameters. Thus, width priority deficiency points, WP, should increase linearly as either ADT or Width Deficiency increases. No extra weighting is needed for very low ADT bridges since the probability of encountering other vehicles on such bridges is low. With low ADT, the usable lane width increases on an otherwise unoccupied bridge.

The width priority is calculated as follows:

$$WP = WW \times \left(\frac{WG - CDW}{3}\right) \times \frac{ADTO}{4000} \qquad \text{(Eq. 4.5)}$$

and the width priority factor is limited to the range $0 \leq WP \leq WW$. The relationships expressed by Equation 4.5 are shown in Figure 4.2.

4.3 Vertical Roadway Under/Over Clearance Priority (VP)

Calculation of vertical clearance priority considers:

UG = Underclearance Goal, Feet (Table 3.3)

VCLU = Present Vertical Underclearance, Feet

ADTU = Average Daily Traffic of Under Route

OG = Overclearance Goal, Feet (Table 3.3)

VCLO = Present Vertical Overclearance, Feet

ADTO = Average Daily Traffic of Over Route

WV = Vertical Clearance Weighting

User costs related to vertical clearance are associated with accident losses, detours of high clearance vehicles and temporary detours resulting from out of service damaged bridges. Public costs include increased insurance premiums and bridge damage repair when accidents occur. In North Carolina, vertical clearance usually involves underclearance for a grade

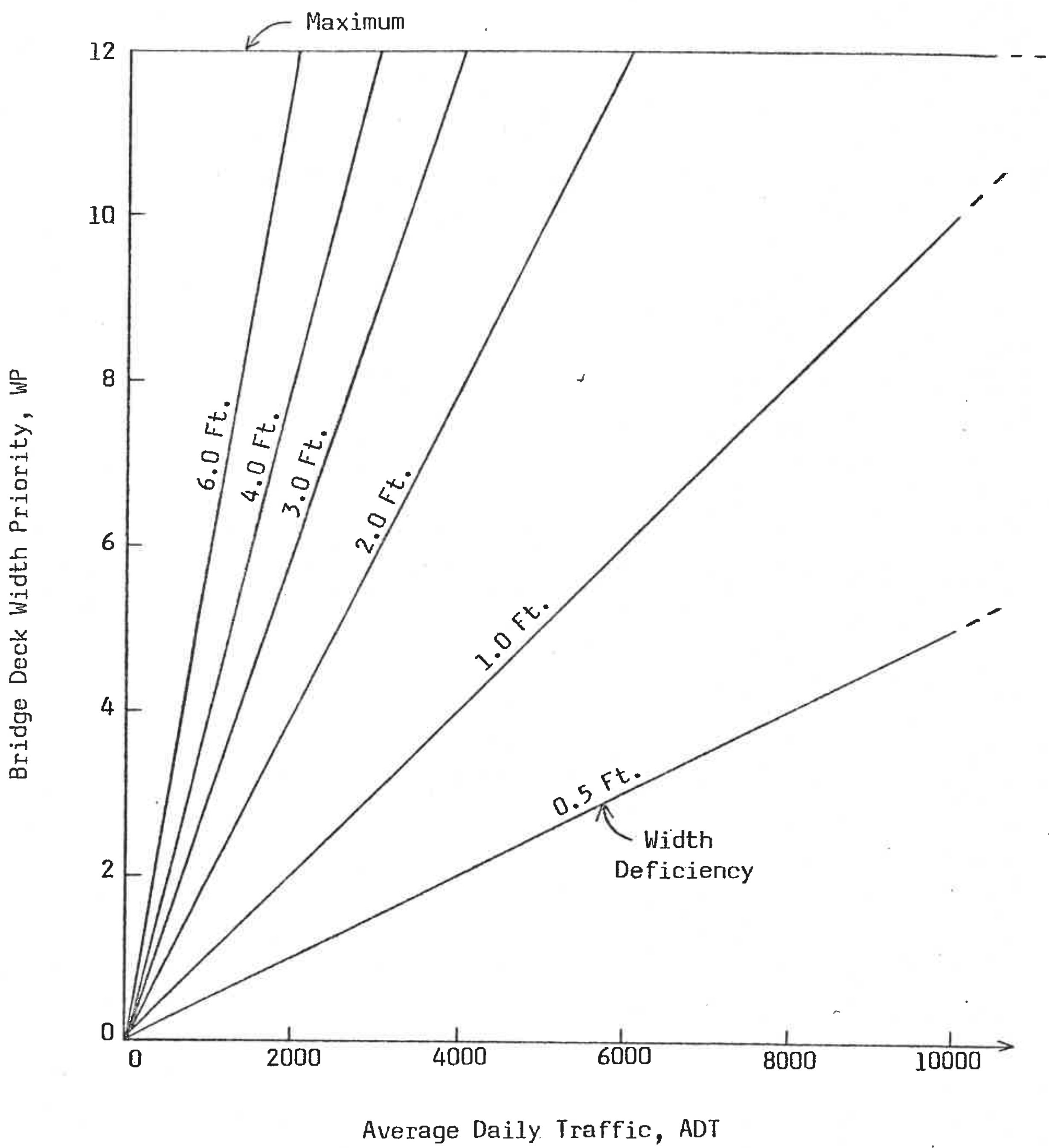

Figure 4.2 Width Priority Versus ADT and Width Deficiency

separation. Overclearance problems are much less numerous since the inventory of thru truss bridges and multiple level bridges at interchanges is small. Nevertheless, both over and under clearance contribute to user costs and both types of clearance problems can occur simultaneously in one bridge.

The magnitude of user and public costs would increase linearly as a function of Vertical Clearance Deficiency (UG-VCLU or OG-VCLO) and Average Daily Traffic. Although the length of detour has an impact upon these costs, the detour length for the route under is not available in the data base. Thus, detour length is not included in the evaluation.

The priority is calculated as follows:

$$VPU = WV \times \left(\frac{UG - VCLU}{2}\right) \times \frac{ADTU}{4000} \qquad \text{(Eq. 4.6)}$$

$$VPO = WV \times \left(\frac{OG - VCLO}{2}\right) \times \frac{ADTO}{4000} \qquad \text{(Eq. 4.7)}$$

$$VP = VPU + VPO$$

and the priority is limited to the range $0 \leq VP \leq WV$. The relationships expressed by Equations 4.6 and 4.7 are shown in Figure 4.3.

4.4 Estimated Remaining Life Priority (LP)

An estimate of remaining life is made by bridge inspectors during the process of inspection. A significant degree of judgement is involved. Many factors appear to be considered including condition ratings, appraisal ratings, load capacity, age, etc. Thus, the estimate is approximate. A remaining life less than 3 years generally indicates significant deterioration. A remaining life above approximately 15 years appears to indicate a generally acceptable situation. Inclusion of estimated remaining life in the analysis is intended to provide some weighting based upon general condition.

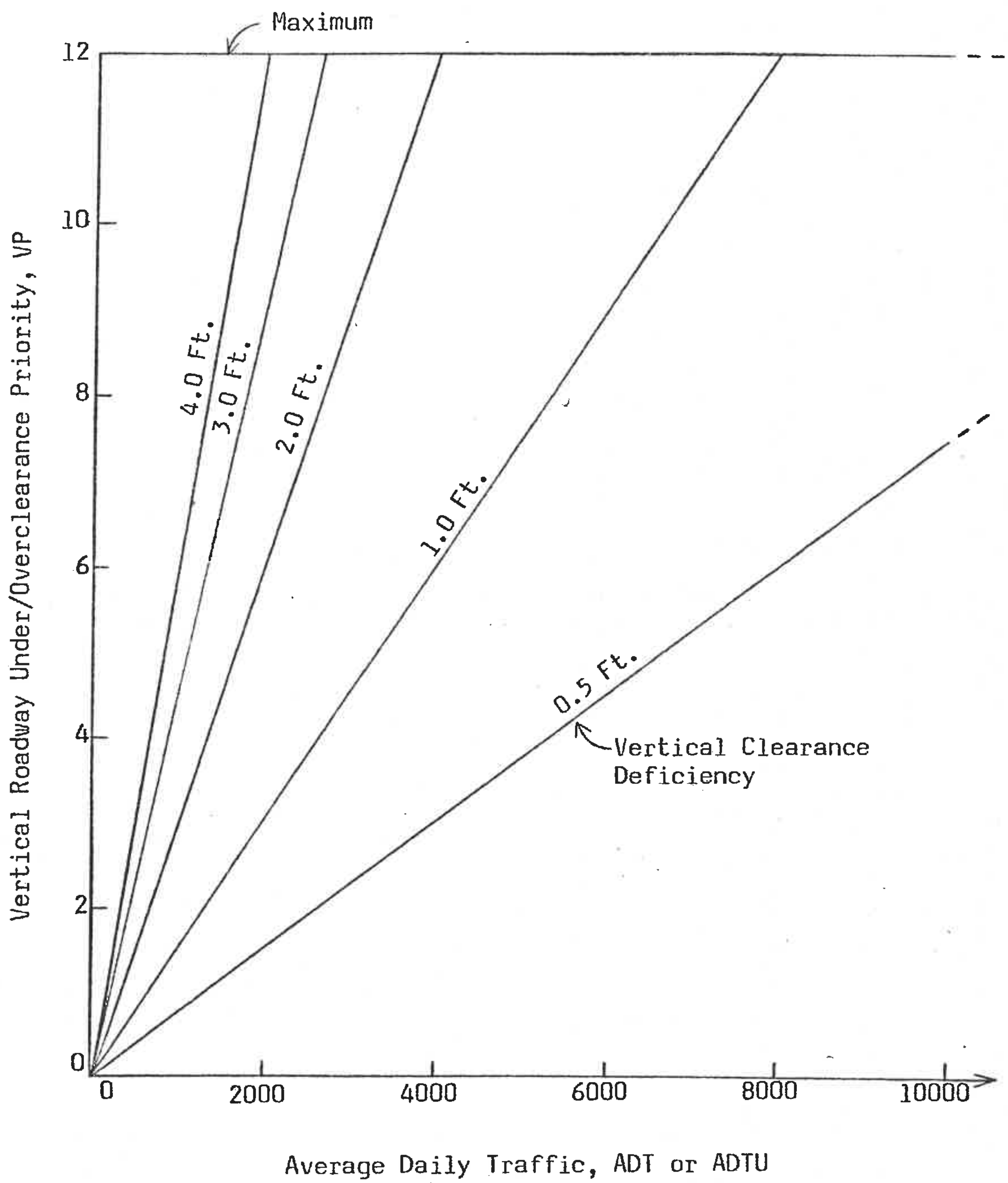

Figure 4.3 Clearance Priority Versus ADT and Clearance Deficiency

The points assigned are a maximum for a remaining life of 3 years or less since the planning, funding, design, and construction process requires approximately 3 years.

Assignment of life priority considers:

RL = Estimated Remaining Life, Years

WL = Remaining Life Weighting

The priority is assigned as follows:

$$LP = WL \times \left[1 - \frac{(RL - 3)}{12}\right] \qquad \text{(Eq.4.9)}$$

and the priority is limited to the range $0 \leq LP \leq WL$. The relationship expressed in Equation 4.9 is shown in Figure 4.4.

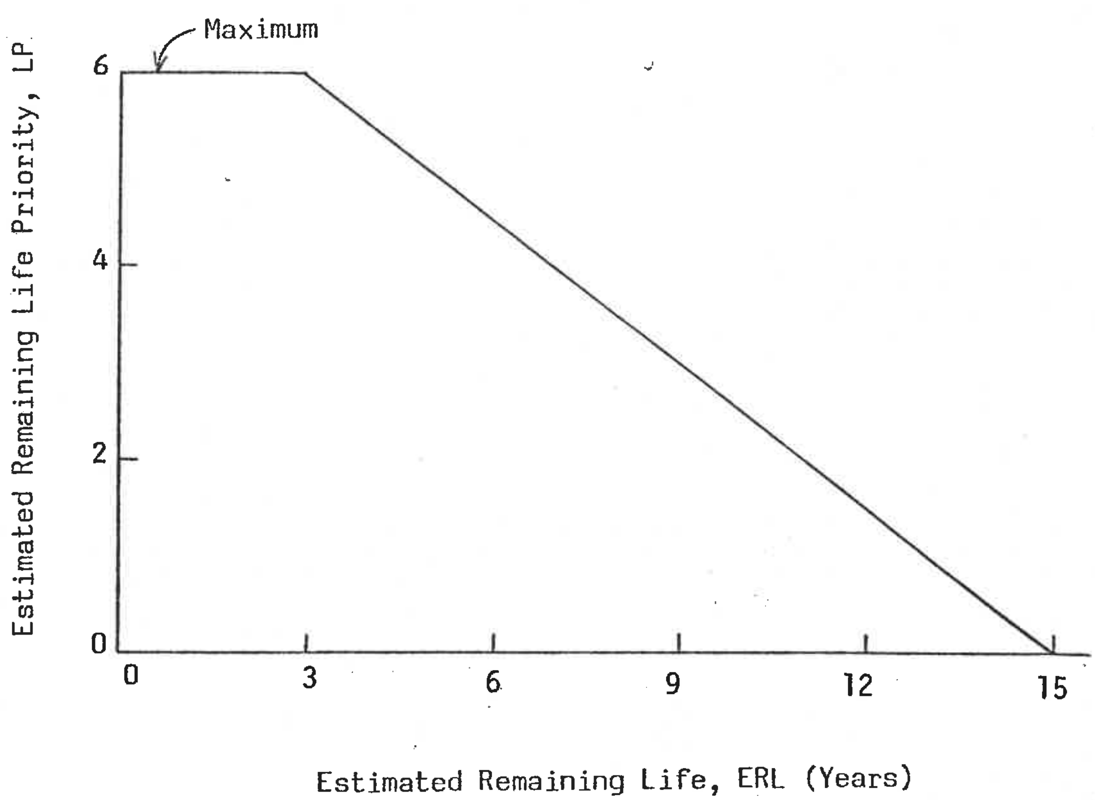

Figure 4.4 Remaining Life Priority Versus Estimated Remaining Life

5. ANALYSIS RESULTS

Data for each bridge from the NCDOT Structure Inventory and Appraisal Expanded File was analyzed using the criteria and methods previously outlined. A computer program, Level of Service and Prioritization (LOSAP), was developed to facilitate data processing. The results of the analysis are printed in various sorting formats to fit the needs of the user. An example of the analysis results based upon acceptable criteria goals is presented in Table 5.1. The results shown are for bridges in the secondary highway system. Sample groups of output lines from the top of the output list, middle of the list and near the bottom of the list are included. Abbreviations for the column headings are further defined in Table 5.2.

Sorting can be accomplished on several levels. Normally, the first level of sorting is either statewide, by system such as interstate, primary, secondary, etc., or by county. The second level of sorting is by Deficiency Points with highest listed first. Other levels and types of sorting and limiters are utilized as needed.

The output printed is intended to provide the user with information that is most frequently utilized in evaluating the circumstances of the bridge being considered for possible replacement, rehabilitation or maintenance. Information groupings include:

1. Bridge identification numbers, location, facility carried and Federal Aid classification.
2. Principal bridge materials, type, condition ratings, age and estimated remaining life.
3. Traffic volume, current capacity, width and underclearance, length, estimated replacement cost and capacity and width goals.

4. Deficiency points, sufficiency rating and cost factor.

The Cost Factor is defined as follows,

$$CF = \frac{\text{Replacement Cost (Thousands)}}{\text{Deficiency Points}} = \frac{RC}{DP}$$

with a maximum value of 999. This factor is an indication of the cost to need ratio. A low cost factor indicates a bridge whose deficiency can be eliminated for a relatively low cost. All parameters of deficiency being equal, it is generally more cost effective to replace a short bridge than a long bridge.

In examining the data sample in Table 5.1, note that the bridges at the top of the list are characterized by high ADT, significant load capacity and width deficiency, and low remaining life. Bridges with zero deficiency have no capacity, width or vertical clearance deficiency and significant remaining life. Bridges with moderate deficiency points usually have moderate deficiencies. However, the deficiencies may be large when the ADT is very low and the detour length is very short.

A frequency distribution of the numbers of bridges in ranges of acceptable and desirable deficiency points is given in Table 5.3. A goal of the Level of Service approach would be to eventually reach a situation in which

1. The average deficiency will be virtually zero when measured against the acceptable level of service goals.
2. The average deficiency when measured against the desirable goals will be allowed to fluctuate in a manner that allows for least cost maintenance, rehabilitation and replacement.

The above recognizes that essential service must be provided with due regard to need for service. However, all bridges cannot be

Table 5.1 Sample LOSAP Output for Secondary Highway System and Acceptable Criteria

SY = S

	OBS	SY	BRNO	STRUCTUR	CNTY	FACILITY	FEDA	SUPMT	SM	AG	RL	DPA	SUFF	CF	LEN	ADTO	SV	CG	CDW	WG	VCLU	DL	DK	SP	SB	RC
High Deficiency	556	S	59212	10090067212U	MECK	SR1009	FAU	ST M-BM	TM	49	2	88.0	2.0	4	125	12500	9	34	20.0	28	0.0	12	4	5	4	338
	557	S	41184	164100301840	HLFX	SR1641	NFA-U	TM M-BM	TM	30	1	88.0	5.0	2	69	4000	17	34	24.0	28	0.0	5	6	6	3	199
	558	S	49	170000470490	ALMC	SR1700	FAU	ST M-BM	TM	33	3	88.0	34.5	1	31	5800	12	34	24.2	28	0.0	3	4	7	6	122
	559	S	73105	153000221050	PITT	SR1530	FAS	TM M-BM	TM	24	2	88.0	35.4	2	69	8700	12	25	24.0	26	0.0	4	5	5	5	209
	560	S	22403	186100804030	CLEV	SR1861	NFA-R	ST F-BM	TM	42	4	87.5	5.0	8	270	6700	4	16	19.5	26	0.0	4	6	4	4	673
	561	S	91100	201200401000	WAKE	SR2012	FAU	ST M-BM	TM	18	4	87.5	10.4	2	36	7200	18	34	24.0	28	0.0	4	5	5	4	133
	562	S	79083	191000630830	ROWN	SR1910	NFA-U	ST F-BM	TM	28	5	87.0	2.0	2	77	3450	6	34	19.2	26	0.0	6	6	7	5	217
	563	S	33113	134800621130	FRSY	SR1348	FAU	ST M-BM	TM	47	5	87.0	27.2	3	82	4800	19	34	22.2	28	0.0	9	7	7	7	239
Moderate Deficiency	1500	S	41058	181500300580	HLFX	SR1815	NFA-R	TM M-BM	TM	31	6	17.0	19.5	9	53	300	10	16	19.1	20	0.0	9	6	5	4	150
	1501	S	10207	274900842070	BUNC	SR2749	NFA-R	ST M-BM	RC	13	10	17.0	42.0	5	23	350	9	16	20.1	20	0.0	3	8	7	5	93
	1502	S	96054	112200760540	WILK	SR1122	NFA-R	ST TR-T	TM	21	5	16.9	21.9	10	62	40	5	16	14.9	20	0.0	6	5	6	6	167
	1503	S	42042	127900450420	HARN	SR1279	NFA-R	ST M-BM	TM	27	4	16.9	47.3	5	21	70	7	16	19.0	20	0.0	4	7	6	7	89
	1504	S	72076	154200380766	PERS	SR1542	NFA-R	TM M-BM	TM	29	8	16.9	36.5	7	35	400	10	16	19.2	20	0.0	5	6	6	6	116
	1505	S	48326	214500823260	IRED	SR2145	NFA-R	ST M-BM	RC	23	8	16.9	17.0	14	97	160	8	16	17.3	20	0.0	3	8	6	4	233
	1506	S	87080	119501000800	TRAN	SR1195	NFA-R	TM M-BM	0	31	6	16.9	40.9	5	21	330	10	16	19.1	20	0.0	2	6	7	6	89
	1507	S	98132	152900771320	YADK	SR1529	NFA-R	ST M-BM	TM	24	5	16.9	40.8	5	22	130	16	16	18.5	110	0.0	5	5	6	5	92
Low Deficiency	6100	S	6175	170000151750	BEAU	SR1700	NFA-R	ST M-BM	TM	21	15	0.0	36.3	999	135	350	27	16	24.0	20	0.0	11	6	7	7	305
	6101	S	62197	201700561970	MOOR	SR2017	NFA-R	PC SLAB	ST	5	43	0.0	36.5	999	126	60	34	16	28.8	20	0.0	99	6	7	5	314
	6102	S	40120	212800491200	GUIL	SR2128	NFA-R	ST M-BM	TM	16	30	0.0	36.7	999	106	440	19	16	24.0	20	0.0	9	8	8	7	250
	6103	S	164	111300471840	ALMC	SR1113	FAS	ST M-BM	TM	34	15	0.0	36.8	999	121	780	25	25	24.0	20	0.0	6	7	7	6	278
	6104	S	78109	176700511090	ROCK	SR1767	NFA-R	ST M-BM	TM	32	20	0.0	37.0	999	90	400	17	16	22.1	20	0.0	10	7	8	8	220
	6105	S	38021	170000370210	GRNV	SR1700	NFA-R	TM M-BM	TM	19	18	0.0	37.9	999	18	320	20	16	23.9	20	0.0	6	6	5	6	84
	6106	S	8105	151100421050	BLAD	SR1511	NFA-R	PC M-BM	TM	11	18	0.0	38.3	999	91	200	19	16	28.9	20	0.0	6	7	7	7	241
	6107	S	24139	147000171390	CRAV	SR1470	NFA-R	PC SLAB	ST	11	38	0.0	38.5	999	182	500	34	16	29.3	20	0.0	30	7	7	8	431

Table 5.2 LOSAP Output Abbreviations

Abbreviation	Definition
OBS	= Output line number
SY	= Highway system (S=Secondary)
BRNO	= Permanent bridge number
STRUCTUR	= Structure number
CNTY	= County
FACILITY	= Facility carried
FEDA	= Federal aid classification
SUPMT	= Superstructure material and type (TM=timber, M-BM=multi-beam/girder)
SM	= Substructure material (ST=steel)
AG	= Age
RL	= Remaining life
DPA	= Deficiency points (acceptable)
SUFF	= Sufficiency rating
CF	= Cost Factor
LEN	= Length
ADTO	= Average daily traffic over bridge
SV	= Single vehicle posting (tons)
CG	= Capacity goal (tons, 34=NP)
CDW	= Clear deck width (feet)
WG	= Width Goal (feet)
VCLU	= Vertical clearance under (feet) (0.0 if not grade seperation)
DL	= Detour length (miles)
DK	= Deck condition rating
SP	= Superstructure condition rating
SB	= Substructure condition rating
RC	= Replacement cost ($ thousands)

Table 5.3 Deficiency Point Distribution

Point Range	Number of Bridges	
	Acceptable	Desirable
DP = 0	7026	4131
0 < DP <= 10	6595	1821
10 < DP <= 20	2309	3150
20 < DP <= 30	476	2561
30 < DP <= 40	165	2132
40 < DP <= 50	82	1294
50 < DP <= 60	48	728
60 < DP <= 70	31	412
70 < DP <= 80	26	267
80 < DP <= 90	30	287
90 < DP <=100	1	6
Total	16789	16789

maintained in new desirable condition indefinitely. Toward the end of bridge life, certain maintenance should be discontinued and some deterioration accepted before replacement so long as essential acceptable levels of service are still provided.

6. CONCLUSIONS

The concept of a Level of Service system offers the following possibilities for bridge evaluation:

1. Acceptable levels of service related to essential public needs can be established in accordance with the functional classification of the highway system being carried.
2. Prioritization for replacement or rehabilitation can be based on the magnitude of the bridge deficiency calculated in a manner which parallels the magnitude of user costs incurred. Optimization techniques for least cost selection among these alternatives are being developed.

Although much effort remains to achieve all the objectives desired, the directions taken to date have enhanced utilization of the bridge inspection data. It is recognized that special needs and situations not accounted for by the system will continue to refine the priority listing. In addition, refinement of the weightings and factors included in the Level of Service analysis is expected to continue. Nevertheless, the system is already greatly assisting in the process of identifying bridges for replacement, rehabilitation and certain maintenance operations.

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3. Bridge Policy, North Carolina Department of Transportation, Division of Highways, Raleigh, 1981.

APPENDICES

Three appendices are included in this chapter. The following is a brief description of each.

Appendix A outlines sorting and listing arrangements for the computer output. During initial development of the analysis system, the program as written in PL/1 utilized the Statistical Analysis System - SAS at N. C. State University for sorting and formating of output. It is envisioned that sorting routines and output formats will have to be built into the program when it is activated on the N. C. State Government ADP system for NCDOT use. The desired sorting and listing options are given in Appendix A.

Appendix B outlines various output listing abreviations and codes. Where the output information is taken directly from the Structure Inventory and Appraisal Expanded File, the column position and field numbers are indicated. Two sheets of output are currently printed: (1) a prioritized listing sorted as desired and (2) a cross reference sheet normally sorted by bridge number.

Appendix C is a listing of the computer program for determining Level of Service and Prioritization Based Upon Need (LOSAP). The program, as listed, is written in PL/1 and uses external subroutines of SAS, the Statistical Analysis System. Descriptive comments and abreviation definitions are included in the listing.

APPENDIX A

COMPUTER OUTPUT SORTING AND LISTING CODES

FOR

BRIDGE MAINTENANCE LEVEL OF SERVICE

AND

PRIORITIZATION BASED UPON NEED

SORTING OPTIONS

A. North Carolina System Definitions

Interstate - Field 153 = 00000 and Field 5 col. pos. 25 = 1
Primary - Field 153 = 00000 and Field 2 col. pos. 9 = 1
Secondary - Field 153 = 00000 and Field 2 col. pos. 9 = 2
Urban - Field 153 not 00000
Municipal - Field 25 col. pos. 149 = 4 (overrides above)

B. County

00 to 99 corresponding to NCDOT Expanded File Column positions 1-2

C. Division

01 to 14 corresponding to NCDOT Expanded file column positions 33-34 (field 6).

D. Deficiency Points (100 to 0) max. first to min. last.

E. Sufficiency Rating (0 to 100) min. first to max. last.

SORTING CODES

0: A-D-E
1: B-A-D-E
2: C-A-D-E
3:
4:
5:

LISTING CODES (Limit amount of output)

0: All Bridges
1: Bridges with Deficiency Points $\geq$ X or Suff. Rating $\leq$ Y.
2: Bridges with Deficiency Points $\geq$ X and Suff. Rating $\leq$ Y.
3: Bridges with Sufficiency Rating $\geq$ X and Suff. Rating $\leq$ Y.
4:

Note: X and Y limits are selected from the range 0 to 100 and entered when needed after the listing code is entered.

APPENDIX B

COMPUTER OUTPUT ABBREVIATIONS AND CODES FOR BRIDGE MAINTENANCE LEVEL OF SERVICE AND PRIORITIZATION BASED UPON NEED

Column Position and Field numbers refer to data locations in the NCDOT Bridge Maintenance Record Expanded File. These are often noted in brackets as [Column Positions; Field].

1. Prioritized Output Listing Sheets

OBS = Observation Number (or output line number)

SY = System (by NCDOT definitions)

I = Interstate : field 153 = 0 & field 5 pos. 25 = 1.
P = Primary : field 153 = 0 & field 2 pos. 9 = 1.
S = Secondary : field 153 = 0 & field 2 pos. 9 = 2.
U = Urban : field 153 not = 0.
W = Municipal : field 25 pos. 149 = 4 (overrides all above).

BRNO = Bridge Number [1-5;-]

STRUCTUR = Structure Number [11-23;3]

FACILITY = Facility Carried by Structure [68-80;part of 11]

FEDA = Federal Aid Classification

System on bridge [163-164;28].

Output Code		Meaning	Computer Code
FAI-R	=	Federal Aid Interstate - Rural	1
FAI-U	=	" " - Urban	2
FAP-R	=	" " Primary - Rural	3
FAP-U	=	" " " - Urban	4
FAS	=	" " Secondary	5
FAU	=	" " Urban	14
LCS	=	Local City Street	12
NFA-R	=	Non Federal Aid - Rural	9
NFA-U	=	" " - Urban	10
FFF	=	Other (check data base for error)	

SUPMT = Superstructure Material and Type

Material for Superstructure Main (field 48) from column position 219 with the following codes:

Output Code	Meaning	Computer Code
RC	Reinforced Conc.	1 or 2
ST	Steel	3 or 4
PC	Prestressed Conc.	5 or 6
TM	Timber	7
MA	Masonry	8
AL	Aluminum	9
O	Other	0

Type of Superstructure Main (field 48) from column positions 220-221 with the following codes:

Output Code	Meaning	Computer Code
SLAB	Slab	01
M-BM	Stringer, Multi-Beam or Girder	02
F-BM	Girder & Floor Beam	03
T-BM	Tee Beam	04
BOXB	Box Beam	05 or 06
FRAM	Frame	07
ORTH	Orthotropic	08
TR-D	Truss - Deck	09
TR-T	Truss - Thru	10
AR-D	Arch - Deck	11
AR-T	Arch - Thru	12
SUSP	Suspension	13
STYG	Stayed Girder	14
MV-L	Movable - Lift	15
MV-B	Movable Bascule	16
MV-S	Movable Swing	17
TNNL	Tunnel	18
CULV	Culvert	19 & Pos. 11=C
PIPE	Pipe	19 & Pos. 11=P
OTHR	Other	00

SM = Substructure Materials

For Pier Substructure Main (field 144) if position 1252 is not blank or zero. Otherwise for Abutment Substructure (field 141) column position 1243.

Output Code	Meaning	Computer Code
RC	Reinforced Concrete	1 or 2
ST	Steel	3 or 4
PC	Prestressed Concrete	5 or 6
TM	Timber	7
MA	Masonry	8
AL	Aluminum	9
O	Other	0

AG	=	Age of Bridge	
		current year minus Date Build 172-173;31	
RL	=	Estimated Remaining Life	
DP	=	Deficiency Points Calculated	
SUFF	=	Sufficiency Rating	
CF	=	Cost Factor ($1000/DP)	
		CF = Estimated Replacement Cost/Deficiency Points	
		CF = 999 when either replacement cost is not available or DP=0.	
LEN	=	Length of Bridge	[239-246;54]
ADTO	=	Average Daily Traffic (latest current)	[180-191;35]
SV	=	Single Vehicle Posting (tons)	
		34 indicates not posted	
CG	=	Single Vehicle Capacity Goal (tons) 34 indicates goal is no posting.	
CDW	=	Clear Deck Width (feet)	[255-259;57]
WG	=	Width Goal (feet)	
VCLU	=	Vertical Underclearance (feet)	[269-272;60]
		Zero if not a grade separation.	
DL	=	Detour Length (miles)	[146-147;23]
DK	=	Deck Condition Rating	[280;64]
SP	=	Superstructure Condition Rating	[282;66]
SB	=	Substructure Condition Rating	
RC	=	Estimated Replacement Cost ($1000)	[330-334;90]

2. Cross Reference Listing Sheets

OBS = Observation Number (or line output number)

DV = N.C. State Highway Division [33-34;6]

SY = System (by NCDOT definitions - see section A above)

BRNO = Bridge Number [1-5;-]

CODE = Sorting and Type Codes (leading 3 digits of str. No.) [9-11;2 & 1st digit of 3]

STRUCTUR = Structure Number (last 12 digits of str No.)

FEATURE = Feature Intersected by Bridge [43-66;9]

FCL = Functional Classification of Route Carried [169; part of 30]

1 = Interstate
2 or 3 = Arterial
4 = Major Collector
5 = Minor Collector
6 = Local

OBSO = Functionally Obsolete Status by Federal Criteria

DEFI = Structurally Deficient Status by Federal Criteria

FEDF = Federal Funding Eligibility

NO = Interstate

REHAB = Eligible for rehabilitation only

RH/RP = Eligible for rehabilitation or replacement

VCLO = Vertical Clearance Over (feet) [265-268;59]

107.25 indicates no obstruction

CP = Capacity Deficiency Points

WP = Width Deficiency Points

VP = Vertical Clearance Deficiency Points

LP = Remaining Life Deficiency Points

DP = Deficiency Points

SUFF = Sufficiency Rating

APPENDIX C

Computer Program Listing

Level of Service and Prioritization (LOSAP)

```
//NSYLVV5 JOB NCS.CE.C5243,SVENDSEN,T=(10),P=800,COMPRESS=NO
// EXEC SAS
//TODAY DD DSN=NCS.CE.C5243.SVENDSEN.SECOND.BRIDGE,DISP=SHR
   DATA SUFF;
   INFILE TODAY;
   ARRAY D(I)$ D1-D5;
   OPTIONS NODATE;
 ********************************************************************
 * BRNO=BRIDGE NUMBER
 * DEFHW=DEFENSE HIGHWAY
 * DETOUR,DL=DETOUR LENGTH
 * LANES=NUMBER OF LANES ON THE BRIDGE
 * ADTO=AVERAGE DAILY TRAFFIC ON BRIDGE
 * ADTU=AVERAGE DAILY TRAFFIC UNDER BRIDGE
 * ARDW=APPROACH ROADWAY WIDTH
 * LEN,LENGTH=LENGTH OF BRIDGE
 * SUP1,STMAIN1=TYPE OF MATERIAL BRIDGE IS MADE OF
 * SUP2,STMAIN2=TYPE OF CONSTRUCTION(GIRDER, TRUSS, ARCH, ETC)
 * BRDW=BRIDGE ROADWAY WIDTH(CLEAR DECK WIDTH)
 * VCLO,VCLO1,VCLO2=VERTICAL CLEARANCE OVER BRIDGE
 * DK,DECK=DECK          RATING
 * SP,SUPERST=SUPERSTRUCTURE  "
 * SB,SUBST=SUBSTRUCTURE      "
 * INV1,INV2=INVENTORY       "
 * STRAPP=STRUCTURAL APPRAISAL
 * DECKAPP=DECK             "
 * UNCLAPP=UNDERCLEARANCE  "
 * WWAYAPP=WATERWAY        "
 * ARDAL=APPROACH ROADWAY ALIGNMENT
 * FACILITY=FACILITY CARRIED BY BRIDGE
 * FA,FEDA=FEDERAL SYSTEM CLASSIFICATION
 * FEDF=TYPE OF FEDERAL FINDING THAT BRIDGE IS ELIGIBLE FOR
 * S11,S22,S33,S44=SAFETY FEATURES
 * VCLU,VCL1,VCL2=VERTICAL CLEARANCE UNDER BRIDGE
 * SC1,SC2,SC5,HIP=SORTING CODES FOR INTERSTATE,PRIMARY,SEC,URBAN
 * RL,ERL=ESTIMATED REMAINING LIFE
 * FCL,FCL1=FUNCTIONAL CLASSIFICATION(OVER,UNDER)
 * DV=NORTH CAROLINA BRIDGE DIVISION
 * SY=STATE SYSTEM CLASSIFICATION
 * STRUCTUR=FEDERAL STRUCTURE NUMBER
 * CNTY=COUNTY NAME ABBREVIATION
 * SUPMT=SUPERSTRUCTURE MATERIAL AND TYPE
 * SM=SUBSTRUCTURE MATERIAL
 * AG=AGE OF BRIDGE
 * DP=DEFICIENCY POINTS CALCULATED
 * SUFF=SUFFICIENCY RATING CALCULATED
 * CF=COST FACTOR
 * SV=SINGLE VEHICLE POSTING(TONS)
 * CULVERT=CULVERT CONDITION RATING
 * CODE=THREE DIGIT ROUTE TYPE CODE
 * PC,RC=REPLACEMENT COST
 * SM1,SM2=SUBSTRUCTURE MATERIAL CODES
 * PIP=FLAG TO DIFFERENTIATE BETWEEN PIPES AND CULVERTS
 * OBSO=FUNTIONALLY OBSOLETE(YES OR NO)
 * DEFI=STRUCTURALLY DEFICIENT(YES OR NO)
```

```
* DEFI=STRUCTURALLY DEFICIENT(YES OR NO)
* **NOTE: ADDITIONAL VARIABLES ARE LISTED BEFORE DEFICIENCY
*             POINT CALCULATIONS.
******************************************************************;
 INPUT BRNO 1-5 DV 33-34 DEFHW$ 120-123 DETOUR 146-147 LANES 176-177
  ADTO 180-185 ADTU 186-191 ARDW 197-199 LENGTH 239-244
  STMAIN1 219 STMAIN2 220-221 BRDW 255-259 VCLO1 265-266 VCLO2 267-268
 DECK$ 280 SUPERST$ 281 SUBST$ 282 CULVERT$ 284 INV1 291
 INV2 292-293 STRAPP$ 294 DECKAPP$ 295 UNCLAPP$ 296
 WWAYAPP$ 298 ARDAL$ 299 ROUTENUM$ 25-32  APPR$ 294-299
 FACILITY$ 68-80 FA$ 163-164 CODE$ 9-11 STRUCTUR$ 12-23
 S11$ 204 S22$ 205 S33$ 206 S44$ 207
 VCL1 269-270 VCL2 271-272 SV 480-481 FEATURE$ 43-62
 SC1 24 SC2 9  SC5 25  HIP 1280-1284 CUSTOD 149
 ERL 285-286 FCX 168-169 FCX1 170-171 PC 330-334 DATEBT 172-173
 SM1 1252 SM2 1243 SUP 219  SUP2 220-221 PIP$ 11  CO 1-2;
********** CODE TO MAKE SURE THAT BRIDGE IS ONLY PICKED UP ONCE *******;
 IF SC1=1;
*************** FUNTIONAL CLASS CODES **********************************;
 IF FCX=11 OR FCX=21 OR FCX=41 OR FCX=1 THEN FCL=1;
  ELSE IF FCX=12 OR FCX=22 OR FCX=42 OR FCX=13 OR FCX=23 OR FCX=43
       OR FCX=14 OR FCX=24 OR FCX=44 OR FCX=2 OR FCX=3 THEN FCL=3;
  ELSE IF FCX=15 OR FCX=25 OR FCX=45 OR FCX=4 THEN FCL=4;
  ELSE IF FCX=5 THEN FCL=5;
  ELSE FCL=6;
**************** FLAGS TO DIFFERINCIATE BETWEEN PIPES AND CULVERTS ****;
 IF PIP='H'  OR PIP='T' OR PIP='S'
    OR PIP='R' OR PIP='W' OR PIP='J' OR PIP='M' OR PIP='G'
  THEN PIP=2; ELSE IF PIP='C' THEN PIP=3;ELSE PIP=1;
 VCLO=VCLO1+VCLO2/12;
 VERTCL=VCLO*100;
 DL=DETOUR;
******************** DETERMINATION OF STATE SYSTEM ********************;
 IF HIP>0 THEN SY='U'; ELSE IF SC5=1 THEN SY='I';
  ELSE IF SC2=1 THEN SY='P'; ELSE SY='S';
 IF CUSTOD=4 THEN SY='W';
****************** DETERMINATION OF FEDERAL SYSTEM ********************;
 IF FA=1 THEN FEDA='FAI-R';
         ELSE IF FA=2 THEN FEDA='FAI-U';
         ELSE IF FA=3 THEN FEDA='FAP-R';
         ELSE IF FA=4 THEN FEDA='FAP-U';
         ELSE IF FA=5 THEN FEDA='FAS';
         ELSE IF FA=9 THEN FEDA='NFA-R';
         ELSE IF FA=10 THEN FEDA='NFA-U';
         ELSE IF FA=12 THEN FEDA='LCS';
         ELSE IF FA=14 THEN FEDA='FAU';
         ELSE FA='FFF';
**************** BEGIN SUFFICIENCY CALCULATIONS **********************;
 IF S11='N' THEN S11=1;
 IF S22='N' THEN S22=1;
 IF S33='N' THEN S33=1;
 IF S44='N' THEN S44=1;
 IF CULVERT = 'N' THEN CULVERTX=8;
    ELSE CULVERTX=CULVERT;
 IF SUBST = 'N' THEN SUBSTX=8;
```

```
      ELSE SUBSTX=SUBST;
   IF SUPERST = 'N' THEN SUPERSTX=8;
      ELSE SUPERSTX=SUPERST;
   IF SUPERSTX LE 2 OR SUBSTX LE 2 OR CULVERTX LE 2 THEN A=55;
    ELSE IF SUPERSTX EQ 3 OR SUBSTX EQ 3 OR CULVERTX EQ 3 THEN A=40;
    ELSE IF SUPERSTX EQ 4 OR SUBSTX EQ 4 OR CULVERTX EQ 4 THEN A=25;
    ELSE IF SUPERSTX EQ 5 OR SUBSTX EQ 5 OR CULVERTX EQ 5 THEN A=10;
    ELSE A=0;
   IF INV1 EQ 1 OR INV1 EQ 3 THEN AIT=INV2*1.56;
    ELSE IF INV1 EQ 2 OR INV1 EQ 9 THEN AIT=INV2;
    ELSE IF INV1 EQ 4 THEN AIT=INV1*1.01;
    ELSE IF INV1 EQ 5 THEN AIT=INV2*.77;
    ELSE IF INV1 EQ 6 THEN AIT=INV2*.67;
   IF AIT>36 THEN AIT=36;
   B=((36-AIT)**1.5)*.2778;
   IF B>55 THEN B=55;
   S1=55-(A+B);
   IF S1<0 THEN S1=0;
   IF DECK='N' THEN DECKX=8;
      ELSE DECKX=DECK;
   IF DECKX LE 3 THEN C=5;
    ELSE IF DECKX EQ 4 THEN C=3;
    ELSE IF DECKX EQ 5 THEN C=1;
    ELSE C=0;
   CCC=C;
   IF STRAPP = 'N' THEN STRAPPX=8;
      ELSE STRAPPX=STRAPP;
   IF DECKAPP = 'N' THEN DECKAPPX=8;
      ELSE DECKAPPX=DECKAPP;
   IF UNCLAPP ='N' THEN UNCLAPPX=8;
      ELSE UNCLAPPX=UNCLAPP;
   IF WWAYAPP = 'N' THEN WWAYAPPX=8;
      ELSE WWAYAPPX=WWAYAPP;
   IF ARDAL = 'N' THEN ARDALX=8;
      ELSE ARDALX=ARDAL;
   D1=STRAPPX;
   D2=DECKAPPX;
   D3=UNCLAPPX;
   D4=WWAYAPPX;
   D5=ARDALX;
   F=0;
   DO  I =1 TO 5;
     IF D LE 3 THEN E=4;
       ELSE IF D EQ 4 THEN E=2;
       ELSE IF D EQ 5 THEN E=1;
       ELSE E=0;
     F=F+E;
   END;
   J=F+C;
   IF J> 13 THEN J=13;
   X=ADTO/LANES;
   Y=BRDW/(LANES*100);
   IF STMAIN2 NE 19 THEN IF (BRDW/100+2)<ARDW THEN G=5;
                           ELSE G=0;
     ELSE DO; G=0; H=0;HG=0; GO TO BB; END;
```

```
IF LANES EQ 1 THEN IF Y<14 THEN H=15;
                  ELSE IF Y<18 AND Y>=14 THEN H=15/4*(18-Y);
                        ELSE H=0;
 ELSE IF LANES EQ 2 AND Y>=16 THEN H=0;
 ELSE IF LANES EQ 3 AND Y>=15 THEN H=0;
 ELSE IF LANES EQ 4 AND Y>=14 THEN H=0;
 ELSE IF LANES EQ 5 AND Y>= 12 THEN H=0;
 ELSE IF Y<9 AND X>50 THEN H=15;
 ELSE IF Y<9 AND X<=50 THEN H=7.5;
 ELSE IF Y>=9 AND X<= 50 THEN H=0;
 ELSE IF X>50 AND X<= 125 THEN IF Y<10 THEN H=15;
 ELSE IF Y>=10 AND Y<13 THEN H=15/3*(13-Y);
 ELSE H=0;
 ELSE IF X>125 AND X<=375 THEN IF Y<11 THEN H=15;
 ELSE IF Y>=11 AND Y<14 THEN H=15/3*(14-Y);
 ELSE H=0;
 ELSE IF X>375 AND X<= 1350 THEN IF Y<12 THEN H=15;
 ELSE IF Y>=12 AND Y<= 16 THEN H=15/4*(16-Y);
 ELSE H=0;
 ELSE IF X> 1350 THEN IF Y<15 THEN H=15;
 ELSE IF Y>=15 AND Y<16 THEN H=15*(16-Y);
 ELSE H=0;
 ELSE H=0;
HG=H+G;
BB:IF DEFHW >0 THEN IF VERTCL >= 1600 THEN Z=0;
                   ELSE Z=2;
   ELSE IF VERTCL>=1400 THEN Z=0;
   ELSE Z=2;
IF HG>15 THEN HG=15;
S2=30-(J+HG+Z);
IF S2 <0 THEN S2 =0;
K=(S1+S2)/85;
IF K=0 THEN DO; S3=0; GO TO AA; END;
P= ADTO*DETOUR*15 /(200000*K);
IF P >15 THEN P=15;
IF DEFHW>0 THEN M=2;
    ELSE M=0;
S3=15-(P+M);
IF S3 <0 THEN S3=0;
AA:SUF1=S1+S2+S3;
R=0;  Q=0;
IF SUF1>=50 THEN DO;
                  T=(DETOUR**4)*5.025*10**-8;
                    DO I=10,12 TO 17;
                            IF STMAIN2=I THEN R=5;
                               ELSE R=0;
                            Q=Q+R;
                    END;
                  K11=0; K22=0; K33=0; K44=0; S55=0;
                  IF S11=0 THEN K11=1;
                  IF S22=0 THEN K22=1;
                  IF S33=0 THEN K33=1;
                  IF S44=0 THEN K44=1;
                  S55=K11+K22+K33+K44;
                  IF S55<=1 THEN C=0;
```

```
                        ELSE IF S55=2 THEN C=1;
                        ELSE IF S55=3 THEN C=2;
                        ELSE C=3;
                     END;
      ELSE DO; T=0; Q=0; C=0; END;
   S4=T+Q+C;
   SUFF=SUF1-S4;
*********************************************************************
* DEFICEINCY POINT CALCULATIONS
*
* WC=WEIGHTING FACTOR FOR CAPACITY
* WW=    "         "    "  WIDTH
* WV=    "         "    "  VERTICAL UNDERCLEARANCE
* WL=    "         "    "  ESTIMATED REMAINING LIFE
* SV=SINGLE VEHICLE POSTING(TONS)
* CDW=CLEAR DECK WIDTH
* CG=CAPACITY GOAL
* WG=WIDTH GOAL
* UGO=UNDERCLEARANCE GOAL OVER BRIDGE
* UGU=UNDERCLEARANCE GOAL UNDER BRIDGE
* LANUM=LANE WIDTH GOAL
* SHO=SHOULDER WIDTH GOAL
* KA,KAW=FACTOR THAT USES ADT OVER BRIDGE
* KAU= FACTOR THAT USES ADT UNDER BRIDGE
* CP= CAPACITY DEFICIENCY POINTS
* WP=WIDTH DEFICIENCY POINTS
* VP=VERTICAL DEFICIENCY POINTS
* LP=LIFE DEFICIENCY POINTS
* DP=TOTAL DEFICIENCY POINTS
* ANY OF THE ABOVE TERMS WITH AN APPENDED 'D' ARE ASSOCIATED WITH THE
* DESIRABLE LEVEL. THE ABOVE TERMS ARE ASSOCIATED WITH THE ACCEPTABLE
* LEVEL.
*******************************************************************;
 WC=70; WW=12;  WV=12; WL=6;
 IF SV=0 THEN SV=33.6;
 ADT=ADTO;
 VCLU=VCL1+VCL2/12;
 CDW=BRDW/100;
********************ACCEPTABLE DEFICIENCY POINTS ********************;
 IF FCL=1 OR FCL=2 OR FCL=3 THEN DO;CG=33.6;
     IF ADT <800 THEN DO;LANUM=10;SHO=1; END ;
        ELSE IF ADT<2000 THEN DO;LANUM=10;SHO=2;END ;
        ELSE IF ADT <4000 THEN DO;LANUM=11;SHO=2; END ;
        ELSE DO;LANUM=11;SHO=3;   END ;END;
   ELSE IF FCL=6 THEN DO; CG=16;
     IF ADT<800 THEN DO;LANUM=9 ;SHO=1;END;
        ELSE IF ADT<2000 THEN DO;LANUM=9 ;SHO=2;END ;
        ELSE IF ADT<4000 THEN DO;LANUM=10;SHO=2;END ;
        ELSE DO;LANUM=10;SHO=3;  END ;END;
   ELSE IF FCL=4 THEN DO; CG=25;
     IF ADT<800 THEN DO;LANUM=9 ;SHO=1;END;
        ELSE IF ADT<2000 THEN DO;LANUM=9 ;SHO=2; END ;
        ELSE IF ADT<4000 THEN DO;LANUM=10;SHO=2;END ;
        ELSE DO;LANUM=10;SHO=3; END ;  END;
   ELSE DO; CG=16;
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          IF ADT<800 THEN DO;LANUM=9 ;SHO=1;END;
             ELSE IF ADT<2000 THEN DO;LANUM=9 ;SHO=2;END ;
             ELSE IF ADT<4000 THEN DO;LANUM=10;SHO=2;END ;
             ELSE DO;LANUM=10;SHO=3;END ;  END;
     WG=LANES*LANUM+2*SHO;
     KA=(ADTO**.30)/12;
     KAW=ADTO/4000;
     KAU=ADTU/4000;
     KD=DL/20;
     CP=WC*(.6*KA+.4*KD*ADTO/4000)*(CG-SV)/(10);
     IF CP <0 THEN CP = 0;
       ELSE IF CP>WC THEN CP=WC;
     WP=WW*KAW*(WG-CDW)/3;
     IF WP<0 THEN WP=0;
       ELSE IF WP>WW THEN WP=WW;
     UG=14.0;
     VPU=WV*((UG-VCLU)/2)*KAU;
     VPO=WV*((UG-VCLO)/2)*KAW;
     IF VPO<0 THEN VPO=0; IF VPU<0 THEN VPU=0;
     VP=VPU+VPO;
     IF VP>WV THEN VP=WV;
     LP=WL*(1-(ERL-3)/12);
     IF LP>WL THEN LP=WL;
     IF LP<0 THEN LP=0.0;
     IF CDW=0 THEN WP=0;
     DP=CP+WP+LP+VP;
    ***********************************************************************
    *  CLASSIFICATION OF FUNCTIONALLY OBSOLETE AND STRUCTURALLY DEFICIENT
    *  BRIDGES. DETERMINATION OF TYPE OF FUNDING THAT BRIDGE IS ELIGIBLE
    *  FOR.
    ***********************************************************************;
     DEFI=' NO'; OBSO=' NO';
     IF DECKX<5 OR SUPERSTX<5 OR SUBSTX<5 OR CULVERTX<5 OR STRAPPX<3
         OR WWAYAPPX<3  THEN DEFI='YES';
     IF DECKAPPX<4 OR UNCLAPPX<4 OR ARDALX<4 OR STRAPPX<4 OR WWAYAPPX<4
        THEN OBSO='YES';
     FEDF='NO    ';
     IF SUFF<80 AND DEFI='YES' THEN FEDF='REHAB';
     IF SUFF<80 AND OBSO='YES' THEN FEDF='REHAB';
     IF SUFF<50 AND DEFI='YES' THEN FEDF='RH/RP';
     IF SUFF<50 AND OBSO='YES' THEN FEDF='RH/RP';
     IF LENGTH<20 THEN FEDF='NO';
    ************ CALCULATION OF DESIRABLE DEFICIENCY POINTS ***************;
     IF FCL=1 OR FCL=2 OR FCL=3 THEN DO;CGD=33.6;
          IF ADT <800 THEN DO;LANUMD=12;SHOD=8; WGD=32;END ;
              ELSE IF ADT<2000 THEN DO;LANUMD=12;SHOD=6;WGD=36;END ;
              ELSE IF ADT <4000 THEN DO;LANUM)=12;SHOD=8; WGD=40;END ;
              ELSE DO;LANUMD=12;SHOD=8; WGD=40;    END ;END;
         ELSE IF FCL=6 THEN DO; CGD=33.6;
          IF ADT<800 THEN DO;LANUMD=11;SHOD=1;WGD=24; END;
              ELSE IF ADT<2000 THEN DO;LANUMD=12;SHOD=2;WGD=28;END ;
              ELSE IF ADT<4000 THEN DO;LANUMD=12;SHOD=3;WGD=30;END ;
              ELSE DO;LANUMD=12;SHOD=3; WGD=30;  END ;END;
         ELSE IF FCL=4 THEN DO; CGD=33.6;
          IF ADT<800 THEN DO;LANUMD=11;SHOD=1;WGD=24;END;
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                ELSE IF ADT<2000 THEN DO;LANUMD=12;SHOD=2; WGD=28;END ;
                ELSE IF ADT<4000 THEN DO;LANUMD=12;SHOD=3;WGD=30;END ;
                ELSE DO;LANUMD=12;SHOD=3; WGD=30;END ;  END;
           ELSE DO; CGD=33.6;
            IF ADT<800 THEN DO;LANUMD=11;SHOD=1;WGD=24;END;
                ELSE IF ADT<2000 THEN DO;LANUMD=12;SHOD=2; WGD=28;END ;
                ELSE IF ADT<4000 THEN DO;LANUMD=12;SHOD=3;WGD=30;END ;
                ELSE DO;LANUMD=12;SHOD=3; WGD=30;END ;  END;
       WGD=LANES*LANUMD+2*SHOD;
      KAD=(ADTO**.30)/12;
      KAWD=ADTO/4000;
      KDD=DL/20;
      CPD=WC*(.6*KAD+.4*KDD*ADTO/4000)*(CGD-SV)/(10);
      IF CPD <0 THEN CPD = 0;
         ELSE IF CPD>WC THEN CPD=WC;
      WPD=WW*KAWD*(WGD-CDW)/3;
      IF WPD<0 THEN WPD=0;
         ELSE IF WPD>WW THEN WPD=WW;
      KAUD=ADTU/4000;
      IF FCX1=11 OR FCX1=21 OR FCX1=41 OR FCX1=12 OR FCX1=22 OR FCX1=42
       OR FCX1=13 OR FCX1=23 OR FCX1=43 OR FCX1=14 OR FCX1=24 OR FCX1=44
       THEN UGD=16.5;
         ELSE UGD=15.0;
      IF FCL=1 OR FCL=2 OR FCL=3 THEN OGD=16.5;
         ELSE OGD=15.0;
      VPUD=WV*((UGD-VCLU)/2)*KAUD;
      VPOD=WV*((OGD-VCLO)/2)*KAWD;
      IF VPUD<0 THEN VPUD=0; IF VPOD<0 THEN VPOD=0;
      VPD=VPUD+VPOD;
      IF VPD>WV THEN VPD=WV;
      LPD=WL*(1-(ERL-3)/12);
      IF LPD>WL THEN LPD=WL;
      IF LPD<0 THEN LPD=0;
      IF CDW=0 THEN WPD=0;
      DPD=CPD+WPD+LPD+VPD;
      DL=DETOUR;
      LEN=LENGTH;
     *************************** CALCULATION OF COST FACTOR *****************;
      IF DP=0 OR PC=0 THEN  CF=999;
         ELSE CF=PC/DP;
      DK=DECK;SP=SUPERST;SB=SUBST;
      FORMAT  DP DPD SUFF CDW VCLU WP CP VCLO VP 4.1;
      IF VCLO=107.25 THEN VCLO=0;
     **************** DETERMINATION OF SUBSTRUCTURE MATERIAL ***************;
      IF SM1=1 OR SM1=2 THEN SM='RC';
        ELSE IF SM1=3 OR SM1=4 THEN SM='ST';
        ELSE IF SM1=5 OR SM1=6 THEN SM='PC';
        ELSE IF SM1=7 THEN SM='TM';
        ELSE IF SM1=8 THEN SM='MA';
        ELSE IF SM1=9 THEN SM='AL';
        ELSE IF SM2=1 OR SM2=2 THEN SM='RC';
        ELSE IF SM2=3 OR SM2=4 THEN SM='ST';
        ELSE IF SM2=5 OR SM2=6 THEN SM='PC';
        ELSE IF SM2=7 THEN SM='TM';
        ELSE IF SM2=8 THEN SM='MA';
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      ELSE IF SM2=9 THEN SM='AL'; ELSE SM='O';
  ************ DETERMINATION OF SUPERSTRUCTURE MATERIAL AND TYPE ********;
   IF SUP=1 OR SUP=2 THEN SU='RC';
      ELSE IF SUP=3 OR SUP=4 THEN SU='ST';
      ELSE IF SUP=5 OR SUP=6 THEN SU='PC';
      ELSE IF SUP=7 THEN SU='TM';
      ELSE IF SUP=8 THEN SU='MA';
      ELSE IF SUP=9 THEN SU='AL'; ELSE SU='O';
   IF SUP2=1 THEN MT=' SLAB'; ELSE IF SUP2=2 THEN MT=' M-BM';
      ELSE IF SUP2=3 THEN MT=' F-BM'; ELSE IF SUP2=4 THEN MT=' T-BM';
      ELSE IF SUP2=5 OR SUP2=6 THEN MT=' BOXB';
      ELSE IF SUP2=7 THEN MT=' FRAM'; ELSE IF SUP2=8 THEN MT=' ORTH';
      ELSE IF SUP2=9 THEN MT=' TR-D';
      ELSE IF SUP2=10 THEN MT=' TR-T';
      ELSE IF SUP2=11 THEN MT=' AR-D';
      ELSE IF SUP2=12 THEN MT=' AR-T';
      ELSE IF SUP2=13 THEN MT=' SUSP';
      ELSE IF SUP2=14 THEN MT=' STYG';
      ELSE IF SUP2=15 THEN MT=' MV-L';
      ELSE IF SUP2=16 THEN MT=' MV-B';
      ELSE IF SUP2=17 THEN MT=' MV-S';
      ELSE IF SUP2=18 THEN MT=' TNNL';
      ELSE IF SUP2=00 THEN MT=' OTHR';
      ELSE IF PIP=1 THEN MT=' PIPE'; ELSE IF PIP=3 THEN MT=' CULV';
      ELSE MT=' ELSE';
   SUPMT=SU||MT;
   AG=83-DATEBT;  RL=ERL;
  ****************** COUNTY ABBREVIATION ********************************;
   IF CO=0 THEN CNTY='ALMC';
      ELSE IF CO=1 THEN CNTY='ALEX';
      ELSE IF CO=2 THEN CNTY='ALLG';
      ELSE IF CO=3 THEN CNTY='ANSN';
      ELSE IF CO=4 THEN CNTY='ASHE';
      ELSE IF CO=5 THEN CNTY='AVER';
      ELSE IF CO=6 THEN CNTY='BEAU';
      ELSE IF CO=7 THEN CNTY='BERT';
      ELSE IF CO=8 THEN CNTY='BLAD';
      ELSE IF CO=9 THEN CNTY='BRWK';
      ELSE IF CO=10 THEN CNTY='BUNC';
      ELSE IF CO=11 THEN CNTY='BURK';
      ELSE IF CO=12 THEN CNTY='CABR';
      ELSE IF CO=13 THEN CNTY='CALD';
      ELSE IF CO=14 THEN CNTY='CAMD';
      ELSE IF CO=15 THEN CNTY='CART';
      ELSE IF CO=16 THEN CNTY='CASW';
      ELSE IF CO=17 THEN CNTY='CATB';
      ELSE IF CO=18 THEN CNTY='CHAT';
      ELSE IF CO=19 THEN CNTY='CHER';
      ELSE IF CO=20 THEN CNTY='CHOW';
      ELSE IF CO=21 THEN CNTY='CLAY';
      ELSE IF CO=22 THEN CNTY='CLEV';
      ELSE IF CO=23 THEN CNTY='COLU';
      ELSE IF CO=24 THEN CNTY='CRAV';
      ELSE IF CO=25 THEN CNTY='CUMB';
      ELSE IF CO=26 THEN CNTY='CURI';
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ELSE IF CO=27 THEN CNTY='DARE';
ELSE IF CO=28 THEN CNTY='DVID';
ELSE IF CO=29 THEN CNTY='DAVE';
ELSE IF CO=30 THEN CNTY='DUPL';
ELSE IF CO=31 THEN CNTY='DURH';
ELSE IF CO=32 THEN CNTY='EDGE';
ELSE IF CO=33 THEN CNTY='FRSY';
ELSE IF CO=34 THEN CNTY='FRNK';
ELSE IF CO=35 THEN CNTY='GAST';
ELSE IF CO=36 THEN CNTY='GATE';
ELSE IF CO=37 THEN CNTY='GRHM';
ELSE IF CO=38 THEN CNTY='GRNV';
ELSE IF CO=39 THEN CNTY='GREE';
ELSE IF CO=40 THEN CNTY='GUIL';
ELSE IF CO=41 THEN CNTY='HLFX';
ELSE IF CO=42 THEN CNTY='HARN';
ELSE IF CO=43 THEN CNTY='HAYW';
ELSE IF CO=44 THEN CNTY='HEND';
ELSE IF CO=45 THEN CNTY='HERT';
ELSE IF CO=46 THEN CNTY='HOKE';
ELSE IF CO=47 THEN CNTY='HYDE';
ELSE IF CO=48 THEN CNTY='IRED';
ELSE IF CO=49 THEN CNTY='JACK';
ELSE IF CO=50 THEN CNTY='JNST';
ELSE IF CO=51 THEN CNTY='JONE';
ELSE IF CO=52 THEN CNTY='LEE ';
ELSE IF CO=53 THEN CNTY='LENO';
ELSE IF CO=54 THEN CNTY='LINC';
ELSE IF CO=55 THEN CNTY='MCDW';
ELSE IF CO=56 THEN CNTY='MACN';
ELSE IF CO=57 THEN CNTY='MADI';
ELSE IF CO=58 THEN CNTY='MART';
ELSE IF CO=59 THEN CNTY='MECK';
ELSE IF CO=60 THEN CNTY='MTCH';
ELSE IF CO=61 THEN CNTY='MONT';
ELSE IF CO=62 THEN CNTY='MOOR';
ELSE IF CO=63 THEN CNTY='NASH';
ELSE IF CO=64 THEN CNTY='NEWH';
ELSE IF CO=65 THEN CNTY='NHMP';
ELSE IF CO=66 THEN CNTY='ONSL';
ELSE IF CO=67 THEN CNTY='ORAG';
ELSE IF CO=68 THEN CNTY='PAML';
ELSE IF CO=69 THEN CNTY='PASQ';
ELSE IF CO=70 THEN CNTY='PEND';
ELSE IF CO=71 THEN CNTY='PERQ';
ELSE IF CO=72 THEN CNTY='PERS';
ELSE IF CO=73 THEN CNTY='PITT';
ELSE IF CO=74 THEN CNTY='POLK';
ELSE IF CO=75 THEN CNTY='RAND';
ELSE IF CO=76 THEN CNTY='RICH';
ELSE IF CO=77 THEN CNTY='ROBE';
ELSE IF CO=78 THEN CNTY='ROCK';
ELSE IF CO=79 THEN CNTY='ROWN';
ELSE IF CO=80 THEN CNTY='RUTH';
ELSE IF CO=81 THEN CNTY='SAMP';
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