Level-of-Service System for Bridge Evaluation

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ABSTRACT

Data collected during federally mandated bridge inspections are a valuable resource. Evaluations based on these data influence levels of federal funding and determine types of funding uses. Nevertheless, the states and other owners have significant flexibility in selecting 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. In this paper research efforts to develop methods to enhance use of North Carolina inspection data by evaluating bridges based on deficiency, as related to acceptable and desirable levels of service, are described. Methods of assigning priorities 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.

The establishment of a federally mandated system for bridge inspection, evaluation, and reporting (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, which ranges from 0 to 100 points, is calculated; the bridge is classified as structurally deficient or not, and as functionally obsolete or not. Depending on the sufficiency rating, a bridge may be eligible for federal funding for replacement or rehabilitation. However, within broad ranges of sufficiency rating (0 to 50 for replacement or rehabilitation and 50 to 80 for rehabilitation), the states may assign priorities for 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 by using the National Bridge Inventory Report Generator program (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 or a trend. Second, methods are needed for assigning priorities of 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, priorities must be based on the degree to which a bridge is deficient in meeting public needs.

With the support of the North Carolina Department of Transportation (NCDOT), a study has been undertaken that had the following objectives:

1. Develop methods to enhance inspection data use in the management of bridge maintenance, rehabilitation, and replacement;
2. Establish a level-of-service system that can serve as a basis for evaluating the adequacy of North Carolina bridges in serving public needs;
3. Assign priorities to bridges in order of need based on 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; and
6. Develop a least-cost maintenance, rehabilitation, and replacement priority system with the capability of estimating future funding needs.

The data in this paper represent a progress report on the results of efforts to achieve these 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.

NATURE OF NORTH CAROLINA BRIDGE PROBLEMS

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

Approximately 65 percent of the bridges in North Carolina are classified as structurally deficient or functionally obsolete, as detailed in the following table:

Classification	No. of Bridges	Percent
Structurally deficient	5,664	34
Functionally obsolete	5,333	31
Neither	5,792	35
Total	16,789	

This relatively high percentage often evokes a public assumption of significant deterioration, but analysis of the inspection data reveals a clearer picture. Figure 1 shows the frequency of condition ratings for the deck, superstructure, and substructure. A rating of 4 (which indicates 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, which indicates that they have been generally well maintained.

Thus the high percentage of structurally deficient bridges is not due to condition as related to maintenance versus deterioration. As the data in the

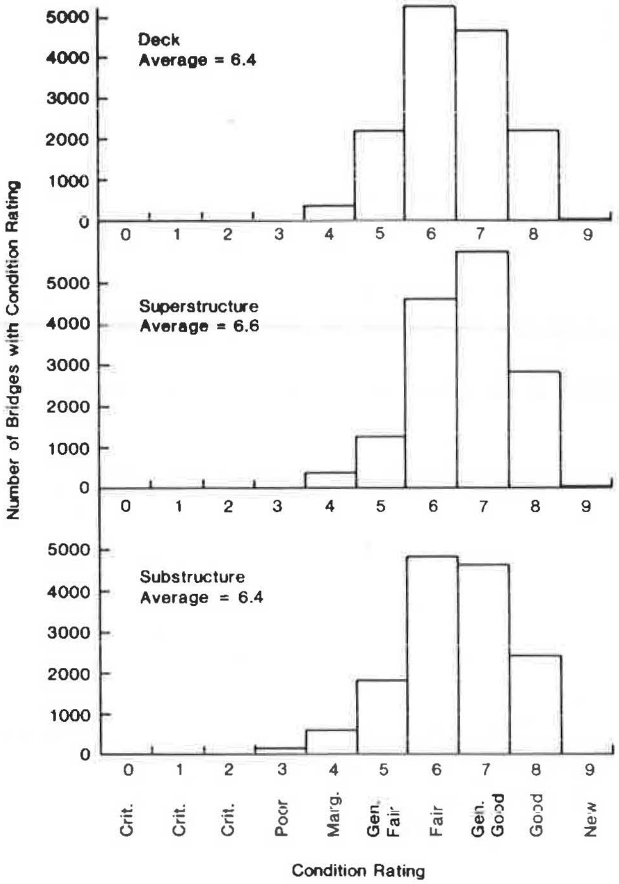

FIGURE 1 Frequency of deck, superstructure, and substructure condition ratings.

following table indicate, the principal cause for classification as structurally deficient is the rating for structural condition (note that the total does not add because it includes some multiple items):

Item	No. of Bridges
Structural condition ≤ 2	5,044
Deck condition ≤ 4	569
Superstructure condition ≤ 4	458
Substructure condition ≤ 4	838
Waterway appraisal ≤ 2	14
Total	5,660

The principal causes for classification as functionally obsolete, according to the data in the following table, are structural condition and deck geometry (note that the total does not add because it includes some multiple items):

Item	No. of Bridges
Structural condition ≤ 3	3,151
Deck geometry ≤ 3	3,009
Approach alignment ≤ 3	1,188
Underclearances ≤ 3	1,163
Waterway adequacy ≤ 3	45
Total	5,333

Some bridges are classified as deficient or obsolete for more than a single cause.

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 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 and HS-15) bridges on low ADT roads. Approximately 3,600 of these bridges have timber superstructures, and many others have timber piles, which further reduce the condition rating. Thus, although many bridges have been maintained in satisfactory condition, the structural condition rating is often 1, 2, or 3, thereby causing the bridge to be deficient or obsolete.

The distribution of posted bridges versus ADT volume is given in Table 1. Although 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. Because determination of sufficiency rating places a heavy weighting on adjusted inventory tonnage, structural condition, and width, the distribution (Table 2) of sufficiency ratings versus ADT volume is similar.

TABLE 1 ADT Versus Single-Vehicle Posting

	No. of Bridges with Single-Vehicle Posting[a] Between					
ADT	3-8	9-15	16-24	25-33	NP	Total
<250	327	2,002	2,354	668	1,220	6,571
250-499	96	647	626	388	711	2,468
500-999	55	380	443	343	802	2,023
1,000-1,999	24	160	223	222	869	1,498
2,000-3,999	6	47	82	128	1,035	1,298
>3,999	4	26	56	136	2,709	2,931
Total	512	3,262	3,784	1,885	7,346	16,789

Note: NP = not posted.
[a]Posting in tons based on operating rating.

TABLE 2 ADT Versus Sufficiency Rating

	No. of Bridges with Sufficiency Rating Between				
ADT	0-25	25-50	50-80	80-100	Total
<250	399	2,832	2,532	808	6,571
250-499	242	1,077	772	377	2,468
500-999	183	736	676	428	2,023
1,000-1,999	123	383	546	446	1,498
2,000-3,999	57	176	462	603	1,298
>3,999	65	252	1,166	1,448	2,931
Total	1,069	5,456	6,154	4,110	16,789

Under federal criteria, a large number of North Carolina bridges are eligible for replacement or rehabilitation funding. However, assigning priorities 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 that more directly considers these factors is needed, especially where the maintenance condition of the bridges is fair to good and the estimated bridge remaining life is relatively long. To meet this need, a level-of-service system has been developed for evaluating and assigning priorities of bridges on the basis of level-of-service deficiency.

BRIDGE LEVEL OF SERVICE

Although it might be ideal to have all existing bridges meet North Carolina Bridge Policy (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 easy-to-quantify characteristics most directly contribute to these needs:

1. Load capacity,
2. Clear bridge deck width, and
3. Vertical roadway underclearance and overclearance.

The level-of-service goal for each of these characteristics will vary, depending on 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, 4, and 6 for capacity, width, and vertical clearance, respectively (note that these tables are presented in a later subsection).]

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 percent of the total highway system based on relative importance for statewide travel.

2. The collector system primarily provides 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 that carry traffic from local roads to arterials are collectors.

3. The 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.

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 or 12 tons. Residential garbage trucks in Raleigh and Wake counties are all two-axle vehicles limited to a legal weight of 15.75 tons. Commercial garbage trucks are often 3-axle or tandem 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 tandem-axle trucks. Medical emergency vehicles weigh up to 4 or 5 tons.

Furthermore, operation of a vehicle weighing more than 15 tons requires a chauffeur's license, which would imply better operator understanding of vehicle weight and posting requirements. Based on these factors, a minimum acceptable load-capacity goal of 16 tons was established (Table 3). 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 and logging trucks.

TABLE 3 Bridge Capacity Goals

Road Over Functional Classification	Single-Vehicle Capacity (tons) Acceptable	Desirable
Interstate and arterial	NP	NP
Major collector	25	NP
Minor collector	16	NP
Local	16	NP

Note: NP = not posted (capacity = 33.6 tons for single vehicles).

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 on the volume of traffic (ADT) and the roadway functional classification (as an indication of traffic content and speed). The acceptable goals given in Table 4 generally correspond to bridge policy for existing bridges to remain in place when

TABLE 4 Clear Bridge Deck Width Goals for Two-Lane Routes

Road Over Functional Classification	Current ADT	Clear Width (ft) Acceptable	Desirable
Interstate and arterial	≤800	22	32
	801-2,000	24	36
	2,001-4,000	26	40
	>4,000	28	40
Major and minor collectors	≤800	20	24
	801-2,000	22	28
	2,001-4,000	24	30
	>4,000	26	30
Local	≤800	20	24
	801-2,000	22	28
	2,001-4,000	24	30
	>4,000	26	30

Note: For bridges with more than two lanes see Table 5. Width = number of lanes (lane width) + 2 (shoulder width).

the approach roadway is reconstructed. However, a width of 26 ft rather than 28 ft was accepted for local and collector systems with ADTs greater than 4,000 vehicles. Also, the current-year ADT is used for the evaluation of acceptability rather than a design-year ADT. The data in Table 4 present width goals for two-lane bridges. For bridges with other than two lanes, the width goals are calculated from the lane and shoulder dimensions given in Table 5.

Vertical roadway underclearance goals affect only those bridges that 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 given in Table 6 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.

TABLE 5 Clear Bridge Deck Width Goals (lane and shoulder)

Road Over Functional Classification	Current ADT	Deck Width (ft) Acceptable Lane	Acceptable Shoulder	Desirable Lane	Desirable Shoulder
Interstate and arterial	≤800	10	1	12	4
	801-2,000	10	2	12	6
	2,001-4,000	11	2	12	8
	>4,000	11	3	12	8
Major and minor collectors	≤800	9	1	10	2
	801-2,000	9	2	11	3
	2,001-4,000	10	2	12	3
	>4,000	10	3	12	3
Local	≤800	9	1	10	2
	801-2,000	9	2	11	3
	2,001-4,000	10	2	12	3
	>4,000	10	3	12	3

TABLE 6 Bridge Vertical Underclearance Goals

Road Under Functional Classification	Underclearance (ft) Acceptable	Desirable
Interstate and arterial	14.0	16.5
Major and minor collectors	14.0	15.0
Local	14.0	15.0

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

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 the current ADT.

ASSIGNING PRIORITIES BASED ON NEED

The method of assigning priorities involves calculation of deficiency points. The four major areas of deficiency to be evaluated are as follows:

Deficiency	Weighting
Single-vehicle load capacity	WC = 70
Clear bridge deck width	WW = 12
Vertical roadway underclearance or overclearance	WV = 12
Estimated remaining life	WL = 6

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

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

$$DP = CP + WP + VP + LP \quad (1)$$

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.

Single-Vehicle Load Capacity Priority

Calculation of capacity priority (CP) considers the following parameters:

CG = capacity goal (tons; see Table 3),
SV = single vehicle posting (tons),
ADTO = average daily traffic of over route,
DL = detour length (miles), and
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), ADT, 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. Although 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 nonlinear factor (KA) increases with ADT but provides somewhat extra consideration for low ADT bridges and bridges with short detour lengths.

The priority is calculated as follows:

$$CP = WC \times [(CG - SV)/10] \times (0.6KA + 0.4KD) \quad (2)$$

where

$$KA = (ADT)^{0.30}/12 \quad (3)$$

$$KD = (DL/20) \times (ADTO/4{,}000) \quad (4)$$

The priority is limited to the range $0 \leq CP \leq WC$. The relationships expressed by Equation 2 are shown in Figure 2.

Clear Bridge Deck Width Priority

Calculation of width priority (WP) considers the following parameters:

WG = width goal (ft; see Tables 4 and 5),
CDW = present clear deck width (ft),
ADTO = average daily traffic of over route, and
WW = width weighting.

User costs related to bridge width are associated

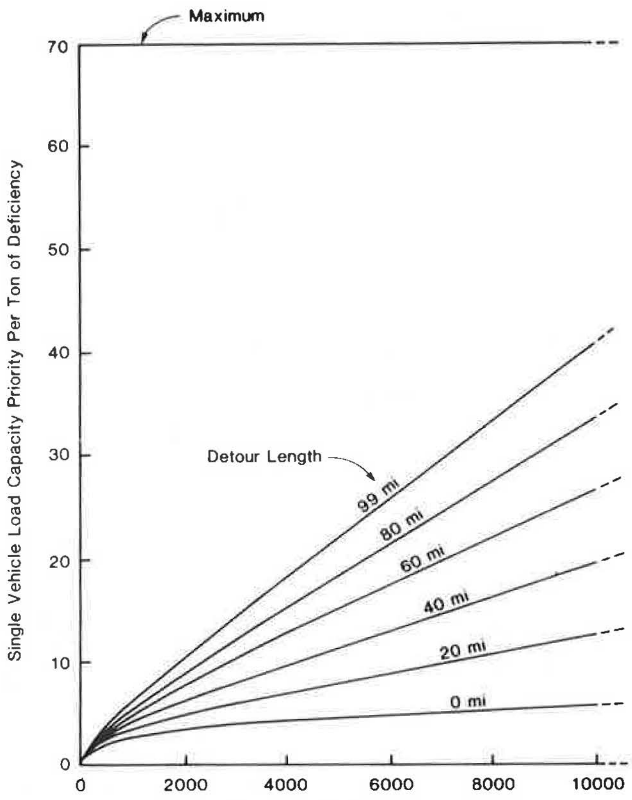

FIGURE 2 Capacity priority per ton versus ADT and detour.

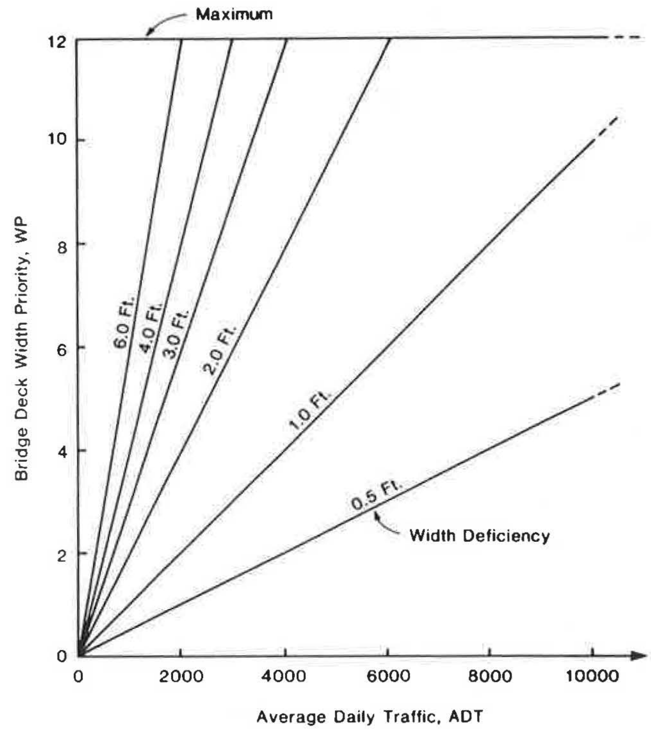

FIGURE 3 Width priority versus ADT and width deficiency.

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, 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 ADT. 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 extremely low ADT bridges because 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:

$$WP = WW \times [(WG - CDW)/3] \times (ADTO/4{,}000) \quad (5)$$

The width priority factor is limited to the range $0 \leq WP \leq WW$. The relationships expressed by Equation 5 are shown in Figure 3.

Vertical Roadway Underclearance and Overclearance Priority

Calculation of vertical clearance priority (CP) considers the following parameters:

UG = underclearance goal (ft; see Table 6),
VCLU = present vertical underclearance (ft),
ADTU = average daily traffic of under route,
OG = overclearance goal (ft; see Table 6),
VCLO = present vertical overclearance (ft),
ADTO = average daily traffic of over route, and
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 separation. Overclearance problems are much less numerous because the inventory of through truss bridges and multiple-level bridges at interchanges is small. Nevertheless, both overclearance and underclearance 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 ADT. Although the length of detour has an impact on 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:

$$VPU = WV \times [(UG - VCLU)/2] \times (ADTU/4{,}000) \quad (6)$$

$$VPO = WV \times [(OG - VCLO)/2] \times (ADTO/4{,}000) \quad (7)$$

$$VP = VPU + VPO \quad (8)$$

The priority is limited to the range $0 \leq VP \leq WV$. The relationships expressed by Equations 6 and 7 are shown in Figure 4.

Estimated Remaining Life Priority

An estimate of remaining life is made by bridge inspectors during the process of inspection. A sig-

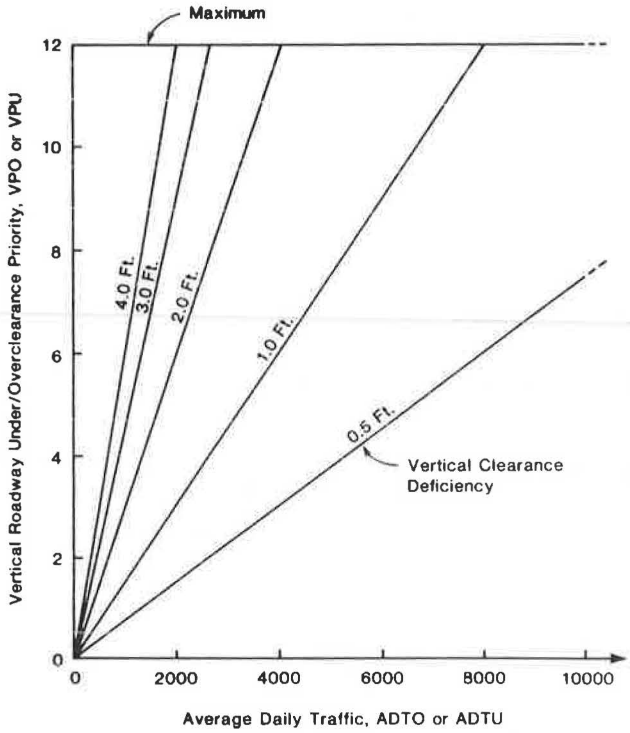

FIGURE 4 Clearance priority versus ADT and clearance deficiency.

nificant degree of judgment is involved. Many factors appear to be considered, including condition ratings, appraisal ratings, load capacity, and age. Thus the estimate is approximate. A remaining life of less than 3 years generally indicates significant deterioration. A remaining life greater than 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 on general condition.

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

Assignment of life priority (LP) considers RL = estimated remaining life (years) and WL = remaining life weighting. The priority is assigned as follows:

$$LP = WL \times \{1 - [(RL - 3)/12]\} \qquad (9)$$

The priority is limited to the range $0 \le LP \le WL$. The relationship expressed in Equation 9 is shown in Figure 5.

ANALYSIS RESULTS

Data for each bridge from the NCDOT Structure Inventory and Appraisal Expanded File was analyzed by 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 on acceptable criteria goals is presented in Table 7. 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

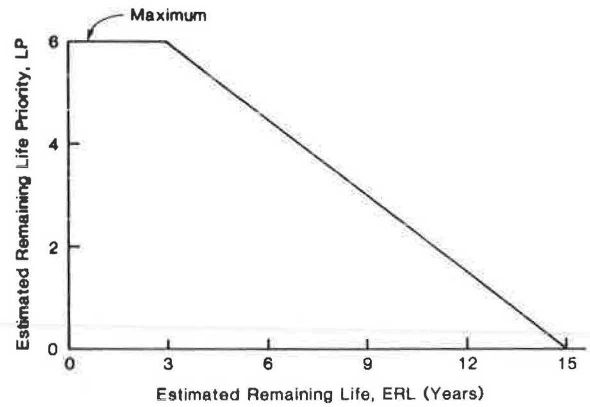

FIGURE 5 Remaining life priority versus estimated remaining life.

near the bottom of the list are included. Abbreviations for the column headings are further defined in Table 8.

Sorting can be accomplished on several levels. Normally, the first level of sorting is either statewide--by system such as Interstate, primary, secondary, and so forth, 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 used as needed.

The output printed is intended to provide the user with information that is most frequently used 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; and
4. Deficiency points, sufficiency rating, and cost factor.

The cost factor (CF) is defined as follows,

$$CF = [\text{Replacement cost (000s)}]/(\text{Deficiency points}) = RC/DP \qquad (10)$$

The maximum value is 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 7, 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 extremely low and the detour length is extremely short.

The sources of the deficiency points accumulated versus acceptable and desirable criteria are shown in Figures 6 and 7. Most of the points are due to load-capacity deficiency because it is heavily weighted. Note, however, that in Figure 6a the number of bridges with a high number of points is small in the acceptable criteria case. The allocation of

TABLE 7 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	08.0	2.0	4	125	12500	9	34	20.0	28	0.0	12	4	5	4	338
	557	S	41104	164100301040	HLFX	SR1641	NFA-U	TM M-BM	TM	30	1	88.0	5.0	2	69	4000	17	34	24.0	20	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	101500300580	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	154200300766	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	0	16.9	17.0	14	97	160	8	16	17.3	20	0.0	3	8	6	4	233
	1506	S	87000	119501000000	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
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	111300471040	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	30021	170000370210	CRNV	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	30	0.0	38.5	999	182	500	34	16	29.3	20	0.0	30	7	7	8	431

life points is the same under both the acceptable and the desirable criteria, as shown in Figure 6b. As shown in Figure 7a, there are a large number of bridges with width deficiency, but most are either on low ADT routes or the width deficiency is not large. There is, however, a concentration of bridges with a large number of width deficiency points that should be eliminated. As shown in Figure 7b, few bridges are deficient in terms of vertical clearance when compared to the acceptable criteria.

A frequency distribution of the numbers of bridges in ranges of acceptable and desirable deficiency points is given in Table 9. 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, and
2. The average deficiency when measured against the desirable goals will be allowed to fluctuate in

TABLE 8 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 = multibeam/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 (ft)
WG	Width goal (ft)
VCLU	Vertical clearance under (ft) (0.0 if no grade separation)
DL	Detour length (miles)
DK	Deck condition rating
SP	Superstructure condition rating
SB	Substructure condition rating
RC	Replacement cost ($000s)

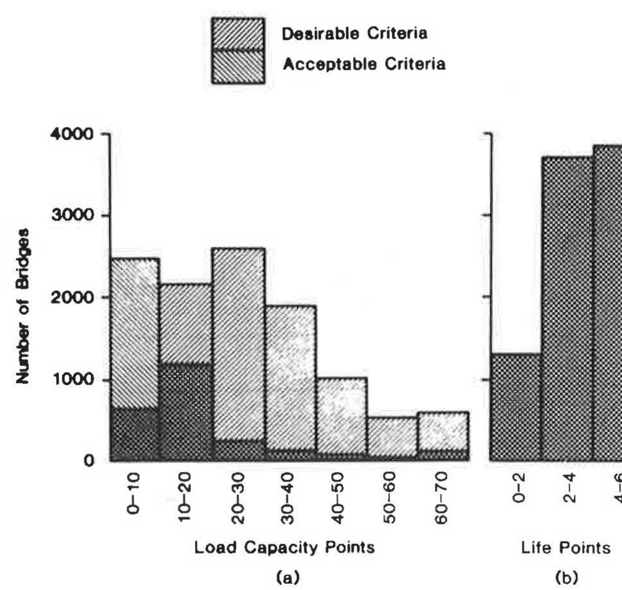

FIGURE 6 Distribution of deficiency points due to load and remaining life.

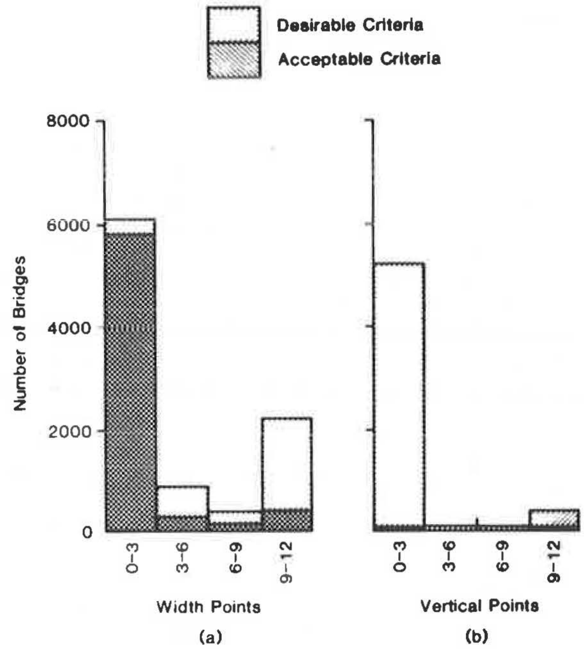

FIGURE 7 Distribution of deficiency points due to width and vertical clearance.

TABLE 9 Deficiency Point Distribution

	No. of Bridges	
Point Range	Acceptable	Desirable
DP = 0	7,026	4,131
0 < DP ≤ 10	6,595	1,821
10 < DP ≤ 20	2,309	3,150
20 < DP ≤ 30	476	2,561
30 < DP ≤ 40	165	2,132
40 < DP ≤ 50	82	1,294
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	16,789	16,789

a manner that allows for least cost maintenance, rehabilitation, and replacement.

This recognizes that essential service must be provided with due regard to need for service. However, all bridges cannot be maintained in a new desirable condition indefinitely. Toward the end of bridge life, certain maintenance should be discontinued and some deterioration accepted before replacement, as long as essential acceptable levels of service are still provided.

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. Assigning priorities for replacement or rehabilitation can be based on the magnitude of the bridge deficiency calculated in a manner that 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 use 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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