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16. Abstract

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A METHOD OF FIELD EVALUATION OF NARROW BRIDGES FOR PRIORITY INDEXING

BY

T. M. Newton

Research Report Number 233-1

Priority Treatment of Narrow Bridges

Research Project 2-18-78-233

Conducted for

THE STATE DEPARTMENT OF HIGHWAYS AND PUBLIC TRANSPORTATION

in cooperation with the

U. S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

by the

TEXAS TRANSPORTATION INSTITUTE
Texas A&M University
College Station, Texas

July, 1979

ABSTRACT

This report is the first in a series dealing with establishing a Priority Index of bridges for passive treatments. Through this evaluation method a cost/benefit relationship allows effective use of available funds at narrow bridges to enable the driver to cross more safely.

Key Words: Narrow Bridge, Bridge Safety, Safety Evaluation, Bridge Width, Bridge Rails, Approach Guardrails.

DISCLAIMER

ACKNOWLEDGMENTS

It is with sincere appreciation that the author acknowledges the co-operation and assistance of the many people whose contributions of time, information, and encouragement made this report possible.

The District Engineers and District Staffs responsible for bridge maintenance at the study sites were ever willing to assist. In the early stages of the study Mr. Ralph K. Banks and Mr. Bernard F. Barton were guides into the Department's Bridge Inspection Report Records. Mr. Edward V. Kristaponis and Mr. Charles Duncan of the Austin Divisional Office of the Federal Highway Administration were always ready to help. Mr. Mike Fraher of the Fort Worth Regional Office of the Federal Highway Administration took part in the field evaluations.

Of those outside of T.T.I., the greatest effort to aid this study was made by Edwin M. Smith, Engineer of Highway Safety. He traveled many miles to evaluate the bridges.

Dr. Robert M. Olson edited this report and prompted the author when the work went slowly. Miss Donna Graves prepared the illustrations and Mrs. Karolyn Smith typed the manuscript.

SUMMARY OF FINDINGS AND RESULTS

This report is the first in a series dealing with establishing a Priority Index of bridges for passive treatment. The sections of the report describe the problems, the purpose, the source, and the field work.

In the study, the Bridge Safety Index was established on fifty bridges. A Field Evaluation Form (see pg. 6 Fig. 2) and a methodology developed in this study were used and field proven. A proposed treatment plan was devised for each bridge. The District Engineer and his staff prepared Treatment Cost Estimates for each proposed treatment plan. Then, the District Priority Index for the sample of bridges was calculated.

This report describes the Field Evaluation Form and enumerates helpful hints on its use. A nomogram for evaluation of the guardrail/transition/bridge rail factor is presented. A photographic scale of the distractions and roadside activities factor is presented.

Two extra Bridge Evaluation Forms with a perforated attachment are placed in the back of the report to aid the user in reproducing the form.

A description of the inspection and rating of the fifty-bridge sample and a summary of the data obtained will be the subject of a later report.

IMPLEMENTATION STATEMENT

The Districts containing the fifty-bridge sample have been visited more than once and will have an advantage with prior knowledge on preparing a Priority Index. Additional Districts will be added each year of the study.

With this report as an instructional manual and the reproduced Field Evaluation Forms, a field study may be commenced by each District. The Bridge Inventory and Inspection Program (BRINSAP) file is the logical point for beginning preparation of the forms. Only bridges on two-lane, two-way roadways are included.

A field evaluation party is formed as directed by the District Engineer. Provision must be made for protection from traffic as the field evaluation is conducted. After the field visit, the Bridge Safety Index (BSI) for each bridge is computed from the data on the evaluation form.

A bridge treatment plan is devised for each site. The costs of the treatments are estimated. The BSI times the AADT divided by the cost of treatment is the Priority Index. The Priority Indices are rank ordered and then may be used to provide the most cost beneficial response to the narrow bridge problem in the District. The program should be initiated using the Priority Indices to upgrade the protection of the narrow bridges in each District.

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The Problem

The problem of narrow bridges has been evident for many years. In the early days of wheeled vehicles many bridges were one-lane structures. However, the increase in density and speed of vehicles created a need for wider structures or improved traffic handling at narrow structures.

Public awareness of the Narrow Bridge Problem escalated in 1972 and 1973. This escalation was brought about by two separate crashes on narrow bridges each involving a semi-trailer truck and a bus. Both accidents had heavy tolls in loss of life.

In mid 1973, the Texas Transportation Institute began its response to demands for action made in U.S. House of Representative Subcommittee Hearings (1) and contacts from the National Cooperative Highway Research Program. This response had three objectives:

1. To define the narrow bridge problem.
2. To appraise the effectiveness of selected corrective measures.
3. To develop guidelines for treatment at narrow bridge sites.

In addition to meeting these objectives in the research report under NCHRP Project 20-7 (2), T.T.I. researchers promulgated a formula for the Bridge Safety Index. This formula has been improved, and its use must be constantly monitored for additional adjustments.

The first field tests of the Bridge Safety Index (BSI) have been conducted with a sample of bridges located in ten highway districts in Texas. The field evaluations on these sample bridges were made by personnel of the

Department from the state and district headquarters, personnel from the Federal Highway Administration, and researchers from T.T.I.

The results of work with the sample of bridges were sufficient to justify the implementation of a Narrow Bridge Priority Indexing of bridges throughout the State.

The Purpose

This report is to serve as a manual for implementation of a Narrow Bridge Priority Indexing (PI).

$$\text{Priority Index} = \frac{\text{BSI x AADT}}{\text{cost of treatments}}$$

After the BSI is determined for the Narrow Bridges in the district, it is multiplied by the Annual Average Daily Traffic, and that product is divided by the Cost of Treatments deemed necessary. When the Priority Index listing is rank ordered, the bridges with the largest indices are candidates for treatment.

The Source

The best source for a list of Narrow Bridges in the district is the Bridge Inventory and Inspection File (3). In addition to the listing of the bridges, several items that will be used in the evaluation can be obtained from this file. Each year, the listing of bridge accidents should be scrutinized. Any high accident location or location with an increase in bridge accidents should be checked to determine if it was omitted from the Narrow Bridge List.

From the file the Bridge Roadway Width, Item 51, and the Approach Roadway Width, Item 32, can be found. If the Bridge Roadway Width is equal to or less than Roadway Width, a structure is a candidate for classification as a Narrow Bridge. The classification is not absolute because of the difference in definition. The T.T.I. report (2) defines Roadway Width as the width of the approach pavement. This definition was used in the field study.

The Bridge Safety Index

To evaluate a Narrow Bridge for safety, the findings of the NCHRP, Project 20-7, Report list the ten Bridge Evaluation Factors shown in Figure 1. A detailed discussion of each factor will be found in the following sections.

$$BSI = \sum_{n=1}^{10} F_n$$

The Bridge Safety Index is the summation of the ten Bridge Evaluation Factors.

The Field Work

In the sample studies the researchers were unacquainted with the local highway system and the bridge locations. It was difficult to find isolated bridges, determine milepost direction, and rely on an independent interpretation of data from varied sources. A definite advantage will occur when studies are made by district personnel because the highways and structures will be known.

	BRIDGE EVALUATION FACTOR	FACTOR RATINGS				
		0	5	10	15	20
F_1	Clear Bridge Width (ft.)	$\leqq 14$	16	18	20	$\geqq 26$
F_2	Bridge Lane Width (ft.) / Approach Lane Width (ft.)	$\leqq 0.8$	0.9	1.0	1.1	$\geqq 1.2$
F_3	Guardrail & Bridge Rail Structure	Use Nomogram in Figure 7 for F_3 Factor Rating				
		1	2	3	4	5
F_4	Approach Sight Distance (ft.) / 85% Approach Speed (mph)	$\leqq 5$	7	9	11	$\geqq 14$
F_5	100 + Tangent Distance to Curve (ft.) / Degree of Curvature	$\leqq 10$	60	100	200	$\geqq 300$
F_6	Grade Continuity (%) $[G_A + \lvert G_1 - G_2 \rvert$	10	8	6	4	$\geqq 2$
F_7	Shoulder Reduction (%)	100	75	50	25	0
F_8	Volume (AADT)/Capacity (VPD)	0.50	0.40	0.30	0.10	0.05
F_9	Traffic Mix	Wide Discontinuities	Non Uniform	Normal	Fairly Uniform	Uniform
F_{10}	Distractions and Roadside Activities	Continuous	Heavy	Moderate	Few	None

FIGURE 1. FACTORS USED TO DETERMINE BRIDGE SAFETY INDEX

District personnel should not merely rely on records in their headquarters, but should use this program to verify and cross-check data shown on other records.

The Bridge Evaluation Data form as used in the sample study is shown as Figure 2. Use of a printed form will aid in organization of activities in the field and preclude the omission of gathering necessary information.

After the field inspection the weighted values are inserted in the margins by the respective box, and the sum is entered at the top of the form. The large spaces at the top were used by the researcher to record BRINSAP and R 12-TLOG references and the accident history for the last three available years.

BRIDGE EVALUATION DATA

BRIDGE NUMBER	DISTRICT	COUNTY	HWY NUMBER	DATE	BSI

BRIDGE MILE POINT	BEGINNING MILE POST	ENDING MILE POST	REPORTED BY

DESCRIPTION ______________________________

____

Approach One Is Heading ____________ From ______________________ (Town).

F_1 CLEAR BRIDGE WIDTH (FT) ______

Bridge Roadway Width
Curb To Curb ____________

F_2 $\dfrac{\text{BRIDGE LANE WIDTH (FT)}}{\text{APPROACH LANE WIDTH (FT)}}$ ______

Bridge Lane Width ____________
Approach Lane Width ____________

F_3 GUARDRAIL & BRIDGE RAIL STRUCTURE ______

	Adequate	Marginal	Inadequate
Guardrail			
Transition			
Bridge Rail			

F_4 $\dfrac{\text{APPROACH SITE DISTANCE (FT)}}{\text{85\% APPROACH SPEED (MPH)}}$ ______

Approach Site Distance ____________
85% Approach Speed ____________

F_5 $\dfrac{\text{100 + TANGENT DISTANCE TO CURVE (FT)}}{\text{DEGREE OF CURVATURE}}$ ______

Tangent Distance To Curve One ____________
Tangent Distance To Curve Two ____________
Degree Of Curve One ____________
Degree Of Curve Two ____________

F_6 GRADE CONTINUITY ______

$G_A + |G_1 - G_2|$

Grade One ____________
Grade Two ____________

F_7 SHOULDER REDUCTION (%)

$\dfrac{S_n - S_b}{S_n}$ ______

Normal Shoulder One ____________
Normal Shoulder Two ____________
Bridge Shoulder One ____________

F_8 $\dfrac{\text{VOLUME}}{\text{CAPACITY}}$ ______

Volume (AADT) ____________
Capacity (VPD) ____________

F_9 TRAFFIC MIX ______

Wide Discontinuities	1
Non-Uniform	2
Normal	3
Fairly Uniform	4
Uniform	5

F_{10} DISTRACTIONS & ROADSIDE ACTIVITIES ______

Continuous	1
Heavy	2
Moderate	3
Few	4
None	5

FIGURE 2. FIELD EVALUATION FORM

The Heading

<table>
<tr><td>BRIDGE NUMBER</td><td>DISTRICT</td><td colspan="2">COUNTY</td><td colspan="2">HWY NUMBER</td><td>DATE</td><td>BSI</td></tr>
<tr><td colspan="2">BRIDGE MILE POINT</td><td colspan="2">BEGINNING MILE POST</td><td colspan="2">ENDING MILE POST</td><td colspan="2">REPORTED BY</td></tr>
<tr><td colspan="8">DESCRIPTION ____
____
Approach One Is Heading ____________ From ____________________ (Town).</td></tr>
</table>

FIGURE 3

Beginning with the Permanent Structure Number, most of the information required in the heading, Figure 3, is self evident. All items should be completed by district personnel in the office, except the date of the evaluation and the name of the recorder for the evaluators.

In the sample study the description blank was used to give directions to the bridge as an aid in event a subsequent visit was required. An economical routing for the sample study necessitated traveling some highways in descending milepost direction. For this reason, the Approach One heading was recorded.

For district use this line should be changed to read, "Approach One is headed with increasing mileposts." Daily return to headquarters allows this ordering to be economical.

Factor F_1

F_1 CLEAR BRIDGE WIDTH (FT) ______

Bridge Roadway Width
Curb To Curb ______

FIGURE 4

The Clear Bridge Width is measured in the field perpendicular to the center line of the highway. Measure between the railings and between the curbs if present. It is necessary to find the lesser distance. Use the Clear Bridge Width to enter Figure 1 to determine the F_1 Factor Rating.

Factor F_2

F_2 $\frac{\text{BRIDGE LANE WIDTH (FT)}}{\text{APPROACH LANE WIDTH (FT)}}$ ______

Bridge Lane Width ______________

Approach Lane Width ______________

FIGURE 5

At a convenient place on the bridge, each lane width is measured. If pavement edge lines are continued across the bridge, they are used to determine the lane width actually provided. If the bridge lane widths are not equal, the lesser figure should be used.

It is impossible to give definite locations for measuring the Approach Lane Widths. Avoid areas within a taper for the bridge approach or a flare for an intersection. The information needed is the Approach Lane Width the driver expects from the roadway he has been traveling. The larger of the two Approach Lane Widths should be used and the worst condition will be determined.

The ratio of the Bridge Lane Width over the Approach Lane Width expressed as a decimal fraction is used to enter Figure 1 to determine the F_2 Factor Rating.

Factor F_3

F_3 GUARDRAIL & BRIDGE RAIL STRUCTURE ______

	Adequate	Marginal	Inadequate
Guardrail			
Transition			
Bridge Rail			

FIGURE 6

The approach guard rail, the transition from the approach guard rail to the bridge rail, and the bridge rail are inspected to determine if each meets currently acceptable standards. The nomogram shown as Figure 7 is used to convert from the word descriptions to a quantitative value for the F_3 Factor Rating.

Examples of the items that must be evaluated are shown in Figure 8.

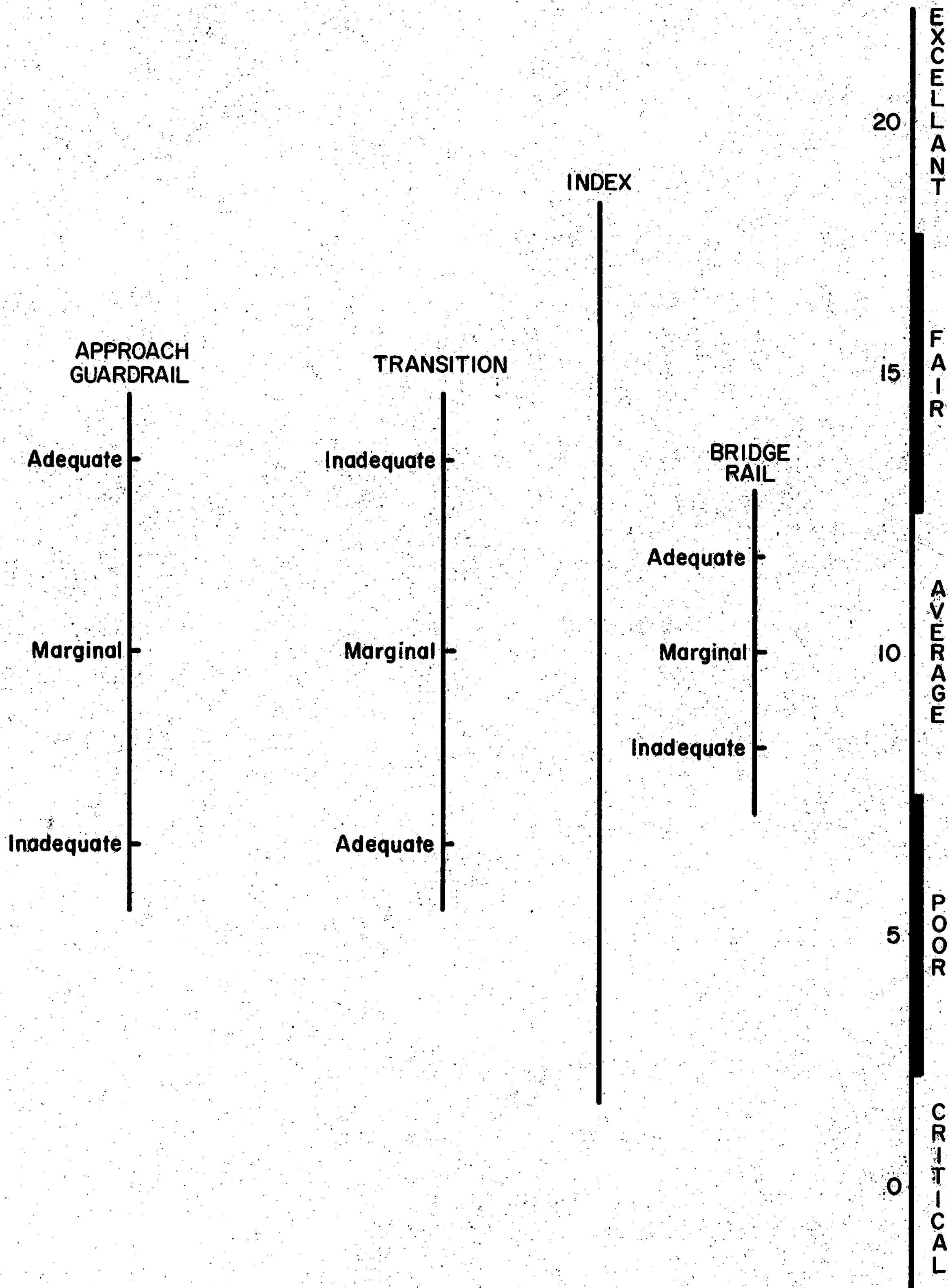
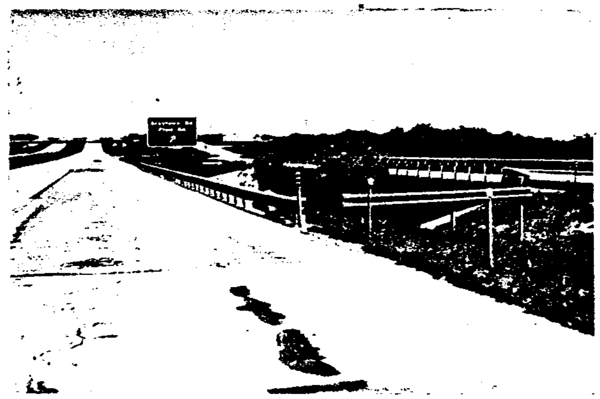
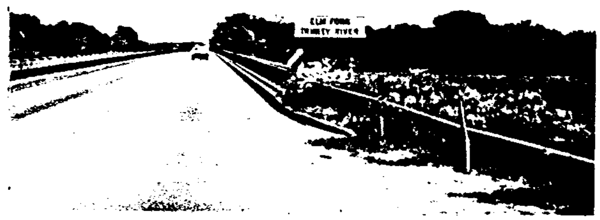


FIGURE 7. F_3 NOMOGRAM

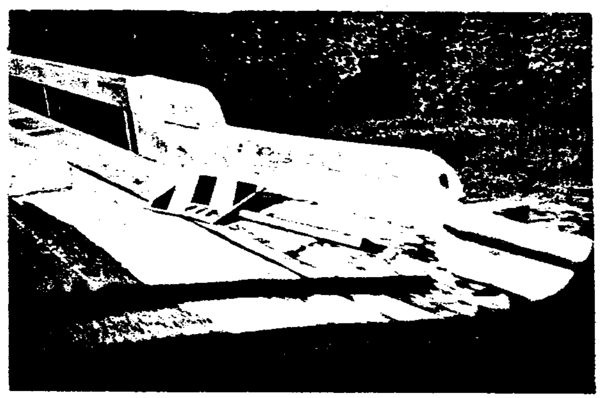
1. CONSIDER THE APPROACH RAIL ENDS



2. CONSIDER POST SIZE AND SPACING CHANGES



3. CONSIDER TRANSITION ATTACHMENT



4. CONSIDER SMOOTHNESS AND ADEQUACY OF BRIDGE RAILS

FIGURE 8. EVALUATION CONSIDERATIONS FOR FACTOR F_3

Factor F_4

F_4	$\frac{\text{APPROACH SITE DISTANCE (FT)}}{\text{85\% APPROACH SPEED (MPH)}}$	______
	Approach Site Distance ____________	
	85% Approach Speed ____________	

FIGURE 9

The Approach Sight Distance is measured from the point where the bridge is clearly discernible to the nearer end of the bridge. The eighty-fifth percentile Approach Speed is determined by radar measurements or from any reliable source. The ratio of Approach Sight Distance in feet over the 85% Approach Speed in miles per hour is used to enter Figure 1 to determine the F_4 Factor Rating.

Factor F_5

$$F_5 \quad \frac{100 + \text{Tangent Distance to Curve (ft)}}{\text{Degree of Curvature}}$$ ______

Tangent Distance To Curve One ______

Tangent Distance To Curve Two ______

Degree Of Curve One ______

Degree Of Curve Two ______

FIGURE 10

The "as built" plans can be used to secure the information needed for Factor F_5. The ratio of 100 plus the Tangent Distance to the Curve in feet over the Curvature in degrees should be found for both approaches. If the degree of curvature does not exceed 5° and the tangent distance exceeds 1400 feet, the maximum rating will occur. The smaller of these two quotients is used to enter Figure 1 to determine the F_5 Factor Rating.

Factor F_6

F_6 GRADE CONTINUITY ______

$$G_A + |G_1 - G_2|$$

Grade One ______

Grade Two ______

FIGURE 11

Grade Continuity is the sum of the average of the grades approaching and leaving the bridge plus the absolute value of the difference in the two grades. This sum is used to enter Figure 1 to determine the F_6 Factor Rating.

Factor F_7

F_7 SHOULDER REDUCTION (%)

$$\frac{S_n - S_b}{S_n}$$ ______

Normal Shoulder One ______

Normal Shoulder Two ______

Bridge Shoulder One ______

FIGURE 12

At the same time that the lane widths are being measured, the shoulder width should be measured. The Normal Shoulder Width of importance on each approach is the right shoulder for the driver approaching the bridge. Only paved shoulders are considered and again it should be measured at a location which will give the shoulder width the driver is expecting and may be using.

The Bridge Shoulder Width is measured, and if the Approach Shoulder Widths are not equal and the Bridge Shoulder Widths are not equal, then the Approach Shoulder Width and Bridge Shoulder Width that applies to one direction of travel and shows the greatest Shoulder Reduction is used. The Shoulder Reduction expressed as a percent is used to enter Figure 1 to determine the F_7 Factor Rating.

Factor F_8

F_8 **VOLUME / CAPACITY** ______ ______

Volume (AADT) ______________

Capacity (VPD) ______________

FIGURE 13

If there has been no obvious change in the traffic using the bridge, the current traffic map can be used to determine the Annual Average Daily Traffic for the bridge. If there has been a change, it will be necessary to make a physical count.

The basic capacity of a two-lane road is 2,000 vehicles per hour. This is the sum of vehicles traveling in opposite directions. It must be reduced for conditions such as obstructions near the traffic lanes (the bridge) and the occurrence of passing sight restrictions. Never will it exceed 48,000 vehicles per day.

Determine the Volume and the Capacity and then get the ratio expressed as a decimal to enter Figure 1 to determine the F_8 Factor Rating.

Factor F_9

F_9 TRAFFIC MIX	______
Wide Discontinuities	1
Non-Uniform	2
Normal	3
Fairly Uniform	4
Uniform	5

FIGURE 14

Uniformity within the District is more important than uniformity statewide or between the Districts. Engineering judgment will be used to convert the observed estimate into one of the five descriptive terms. Variations that are seasonal, weekend recreational traffic, or other discontinuities may not be evident on the day of an inspection, but should be sought out by interviews with the people that know the community. Spasmodic interruptions that do not represent a trend with long lasting effects should be minimized.

When the descriptive term is selected, the rating form provides the quantitative value for Factor F_9.

Factor F_{10}

F_{10} DISTRACTIONS & ROADSIDE ACTIVITIES	______
Continuous	1
Heavy	2
Moderate	3
Few	4
None	5

FIGURE 15

Any unusual activity or environment can cause the occupants of a vehicle to fail to concentrate their attention on the task of safely crossing a narrow bridge. A panorama of the mountains, the sea, or a city is often viewed easiest from the approaches of a bridge as it spans an unwooded area. A beautiful, pleasurable distraction can be just as deadly as one that is repugnant.

Again, engineering judgment will be used to convert the observed estimate into one of the descriptive terms. The rating form provides the quantitative value for Factor F_{10}.

The five photographs shown as Figures 16 through 20 can be used as a guide to discuss the distractions and roadside activities in your area.

FIGURE 16. F_{10} RATING OF 1.

There are continuous distractions, crosstraffic, driveways and intersections. Industrial sprawl has moved onto the right of way with the random parking of vehicles. At quitting time there are only two ways for the workers to depart. A community is in the trees in the background.

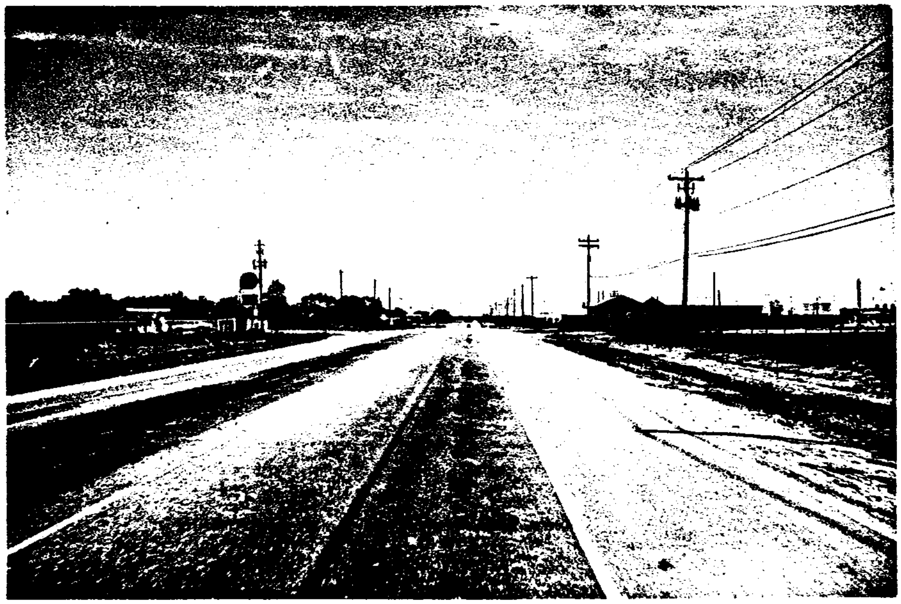


FIGURE 17. F_{10} RATING 2.

The industry to the right is located farther from the roadway. For the traveler the petrochemical complex may distract the occupants. Even a small service station generates many entries, exits and non-intersection left turns each day.

FIGURE 18. F_{10} RATING 3.

Gracious landscaping and beautiful homes distract motorists. The realization comes that distractions and activities may be pleasant or distasteful but still keep the driving task from being done safely.

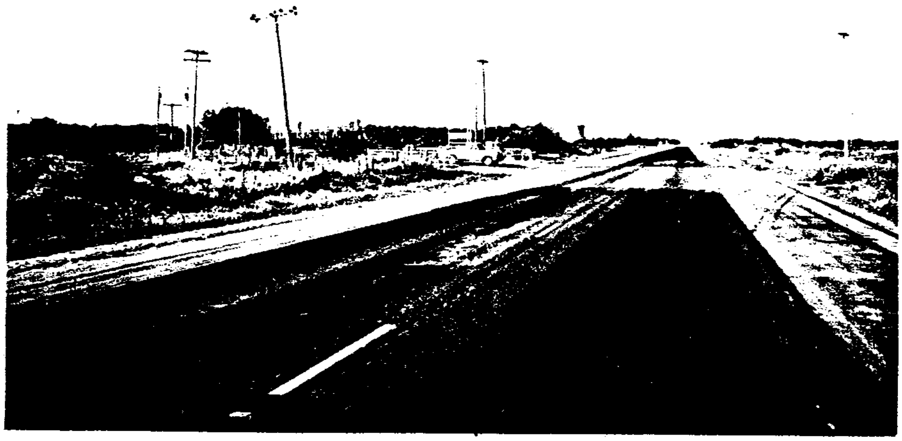


FIGURE 19. F_{10} RATING 4.

The railroad on the right shields the highway from penetration and seldom distracts with a few trains a week. Only one side road comes into the highway and the physical evidence indicates little traffic on it. The brush in the pastures screens anything that might interest the traveler.

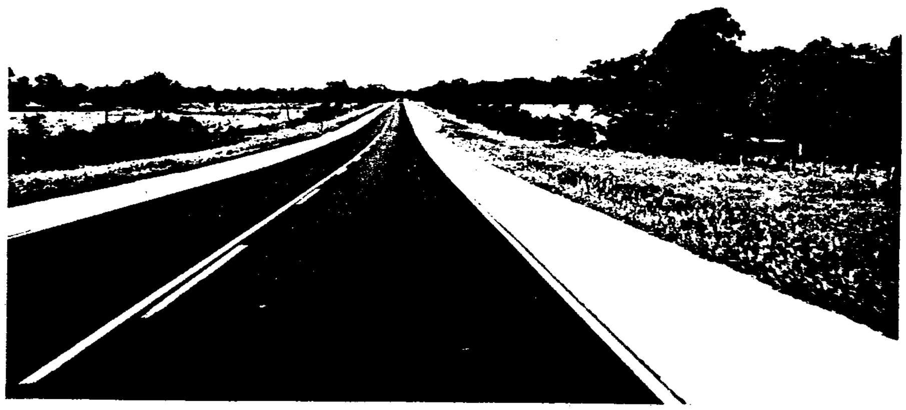


FIGURE 20. F_{10} RATING 5.

There are no distractions on this highway. No intersections, driveways or side roads require the driver's attention. Most travelers would consider the scenary dull. Monotony is not rated under F_{10}.

REFERENCES

1. Ninety-Third Congress, First Session, Hearings Before the Subcommittee on Investigations and Review of the Committee on Public Works, House of Representatives, Washington, D.C., June 12-14, 1973.

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4. "Bridge Inventory, Inspection and Appraisal Program (BRINSAP), Manual of Procedures," Texas State Department of Highways and Public Transportation, 1977.