ECONOMIC AND SAFETY CONSIDERATIONS FOR ESTABLISHING MINIMUM LATERAL OBSTACLE CLEARANCE POLICIES FOR UTILITY FACILITIES IN NEBRASKA URBAN AND SUBURBAN AREAS

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ABSTRACT

The Nebraska Department of Roads (NDOR) is reviewing the Federal Highway Administration's (FHWA's) policy for lateral obstacle clearance or offset for utility facilities on curbed sections along new or reconstructed municipal state highways in urban areas. The FHWA requires that utility appurtenances such as fire hydrants, utility poles (electrical distribution or transmission), light poles or luminaires, gas pipeline structures, etc., be located at a 6 ft minimum lateral offset from the back of the curb for new or reconstructed municipal state highways.

Since accidents involving utility poles are associated with one of the higher rates of accident severity, a considerable reduction in both accident frequency and accident severity could be obtained by specifically studying and analyzing utility pole installations. Basic street lighting and fire hydrants were also emphasized in the study.

The cost-effectiveness methodologies selected for use in the study were presented in Federal Highway Administration report number FHWA-IP-86-9, "Selection of Cost-Effective Countermeasures for Utility Pole Accidents--User's Manual," by Zegeer and Cynecki; and the American Association of State Highway and Transportation Officials' (AASHTO) publication entitled, "Roadside Design Guide" 1988.

Computer models were developed for both methodologies. The first, "UPACE," was intended for use with utility installations having multiple appurtenances in a line or a row, for example, a line of power poles; the second, "ROADSIDE," was intended for use with single utility installations such as fire hydrants. Seven actual safety improvement projects were analyzed with "UPACE" to evaluate current standards and their effectiveness, obtain actual field data, and validate various parts of the computer model.

After the site-specific analyses were completed, it was evident that a more detailed breakdown was needed for the various typical utility installations. Accordingly, general site analyses were performed with "UPACE" for various typical utility installations such as street lighting, power distribution, power transmission, and breakaway light and utility poles. A benefit-to-cost ratio methodology was used as the basis for the results and conclusions. General site analyses were also performed with "ROADSIDE" for various typical single utility installations such as utility poles, light poles, and fire hydrants; and for one actual site, a gas installation.

Some of the key questions which were evaluated were (1) whether it was cost-effective to relocate a line of poles, and at what lateral distance it became cost-effective, (2) whether the relocation of poles was more cost-effective than modification of existing poles to be breakaway, (3) whether it was cost-effective to relocate a single utility installation, such as a power pole, light pole, and fire hydrant, and at what lateral distance it became cost-effective, (4) whether the relocation of a single utility installation was more cost-effective than modification of the installation to be breakaway, and (5) whether the 6 ft minimum lateral offset was adequate.

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1 INTRODUCTION

1.1 Problem Statement

The Nebraska Department of Roads (NDOR) is reviewing the Federal Highway Administration's (FHWA's) policy regarding the lateral obstacle clearance of utility facilities in urban areas. The FHWA requires that utility appurtenances such as fire hydrants, utility poles (electrical distribution or transmission), light poles or luminaires, etc., be located at a 6 ft minimum lateral offset from the back of the curb for new and reconstructed municipal state highways. Along a new or reconstructed municipal state highway which is classified as either a curbed arterial or collector, for example, current FHWA policy is that the lateral obstacle clearance is to be located 6 ft from the back of the curb.

NDOR's concern is whether this required offset is excessive (conservative) or unsatisfactory, and whether the safety value to be gained from increasing the lateral obstacle offset distance warrants the additional cost. That is, is the 6 ft minimum distance more economical and effective than a 2 ft minimum?, and, what factors determine what distances are cost-effective?

1.2 Objective

The two most common hazardous, fixed-object obstacles existing along the roadways are utility and light poles. NDOR judged that the high rate of accident severity associated with utility and light poles, and the potential for a considerable reduction in accident frequency and severity, warranted study and analysis of various pole installations. The major objective of the study was to determine the minimum distance location of power and light poles. Countermeasures for fire hydrants were also considered in the study.

A benefit-to-cost ratio methodology served as the basis for the analysis; optimum lateral obstacle clearance was determined by considering the safety benefit obtained with respect to the cost of constructing the improvement. Results of the study were used to generate curves and/or tables for use by Nebraska Department of Roads staff as a tool or aid in selecting the optimum location for utility facilities, that is (1) a line of utility poles or luminaires or (2) a single power pole, light pole, or fire hydrant.

1.3 Scope

Five previously constructed or reconstructed and two future improvement projects were analyzed. The field sites were selected by the Nebraska Department of Roads, and all involved either utility or light pole improvements. The sites were located in Omaha, Lincoln, and Wayne, Nebraska. Each of the seven sites was visited for data collection to perform the cost-effectiveness analysis.

1.4 Organization

Chapters 2, 3 and 4 present summary and background information on lateral obstacle clear zone policies in each of the fifty states and Puerto Rico, an accident literature review, and a review of government policy literature on lateral obstacle clear zones. In Chapter 5 cost-effectiveness research studies dealing with safety improvements for fixed objects and the conceptual model which served as the basis for the "UPACE" and "ROADSIDE" methodologies are reviewed. Chapters 6, 7, and 8 discuss the "UPACE" methodology, field sites, and general site analyses, respectively; in Chapter 9 the general site analyses for the "UPACE" model are presented. Similarly, Chapter 10 presents the "ROADSIDE" methodology, and Chapters 11 and 12 the general and specific site analyses. Conclusions and recommendations are presented in Chapter 13, and finally, in Chapter 14 reimbursement policies to utilities are reviewed.

2 LATERAL OBSTACLE CLEAR ZONE POLICIES

2.1 Background

The Federal Highway Administration (FHWA) currently requires that a 6 ft minimum lateral offset from the back of the curb be maintained for location of utilities along new or reconstructed municipal state highways and municipal streets in urban areas. However, lateral obstacle offset policies vary from state to state. To compare the policies used by the State of Nebraska with those of other states, a questionnaire was prepared and sent to each of the fifty state highway departments and Puerto Rico. The departments were also requested to send a copy of their current standards.

2.2 Objective

The purpose of the review was to better understand current lateral obstacle clear zone policies in other states and also to review the factors which influenced the formation of those policies. Emphasis was placed on urban and suburban classifications.

2.3 Scope

Information was sought on minimum design standards for all roadway functional classifications. More specific information was requested on lateral obstacle policies for municipal streets, and specifically the validity of the 6 ft minimum lateral offset along municipal streets. A copy of the cover letter, questionnaire, and two examples from the Nebraska Department of Road's (NDOR) minimum design standards are included in Appendix A.

2.4 Questionnaire Summary

The first questionnaire, *Questionnaire #1*, was entitled, "*Lateral Obstacle Clear Zone Policies for Fixed Objects Located on Municipal Streets.*" (Refer to Appendix A for a review of the questions.) Responses to the questionnaire are presented in Table 1 and summarized in Table 2. Eight states did not respond to the questionnaire. The questions and responses are discussed below.

Question #1:

The purpose of this question was to determine how many states currently have a lateral obstacle clear zone policy for fixed objects such as utility facilities, trees, etc., along curbed municipal streets. The summary presented in Table 2 shows that 31 (81.6%) of the 38 states responding to the question do have specific policies. Of the states that reported a clear zone distance, the average clear zone distance was 3.4 ft for curbed sections along municipal streets. One state reported that the clear zone distance varies, and three states responded that they use the AASHTO "Roadside Design Guide" for their clear zone criteria.

Question #2:

The intent of this question was to determine how many states currently have a lateral obstacle clear zone policy for fixed objects along non-curbed municipal streets. Results presented in Table 2 indicate that 29 (80.6%) of 36 states responding to the question have a specific policy. The states that reported a clear zone distance used an the average of 10.3 ft for non-curbed sections along municipal streets. Seven states reported that the clear zone distance varies, nine stated that they use the AASHTO "Roadside Design Guide", and one reported that they use the AASHTO "Guide for Selecting, Locating, and Designing Traffic Barriers" for their clear zone criteria.

TABLE 1.
Questionnaire #1 Responses

Lateral Obstacle Clear Zone Policies for Fixed Objects Located on Municipal Streets

State	Lateral Clear Zone Policy for Curbed Municipal Street			Lateral Clear Zone Policy for Non-Curbed Municipal Street			Policy Dependent on Concurrent Safety Improvement Project		Consideration for Shielded Poles for Relocation		Consider Using FHWA "UPACE" Economic Computer Model	
	Yes	No	Distance (ft)	Yes	No	Distance (ft)	Yes	No	Yes	No	Yes	No
1. Alabama	xxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx
2. Alaska	Yes		2*	Yes		7-10	Yes		Yes			Unfamiliar
3. Arizona		No	RDG		No	RDG	Yes		Yes		—	–
4. Arkansas	Yes		5	Yes		RDG	Yes		Yes		Yes	
5. California		No	—		No	—	—	–	No		—	–
6. Colorado	Yes		1.5*	Yes		RDG	Yes		Yes			Unfamiliar
7. Connecticut	Yes		1.5*	Yes		10	Yes		Yes			Unfamiliar
8. Delaware	Yes		2-6	Yes		Varies	No		Yes			No
9. Florida	xxxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx
10. Georgia	Yes		6*	Yes		RDG	Yes		Yes			No
11. Hawaii	Yes		2	Yes		17	Yes			No	—	–
12. Idaho	—	–	—	—	–	—	—	–	—	–	—	–
13. Illinois	Yes		1.5*	Yes		10	Yes		Yes			Unfamiliar
14. Indiana	Yes		1.5*	Yes		10	Yes			No	—	–
15. Iowa	Yes		10	Yes		Varies	Yes		Yes			No
16. Kansas	Yes		6-8	Yes		YB	Yes		Yes		Yes	
17. Kentucky	Yes		6-9.5	Yes		—	Yes			No	—	–
18. Louisiana	xxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx
19. Maine	Yes		Varies	Yes		Varies	Yes			No	—	–
20. Maryland	Yes		7*	Yes		12	Yes		Yes			No
21. Massachusetts	—	–	—	—	–	—	—	–	—	–	—	–
22. Michigan	xxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx
23. Minnesota	Yes		2	Yes		Varies	Yes		Yes		—	–
24. Mississippi	Yes		1.5*	Yes		10	—	–	—	–	—	–
25. Missouri		No	—		No	—	—	–		No	—	–
26. Montana	Yes		2*	—	–	—	Yes		Yes		—	–
27. Nebraska	Yes		2	Yes		8	Yes		Yes		Yes	
28. Nevada	xxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx
29. New Hampshire	Yes		1.5*	Yes		8[t]	Yes		Yes		Yes	
30. New Jersey	—	–	1.5	—	–	—	—	–	—	–	—	–
31. New Mexico	Yes		RDG	Yes		RDG	Yes		Yes		Yes	
32. New York	—	–	—	—	–	—	—	–	—	–	—	–
33. North Carolina	Yes		6	—	–	Varies	Yes			No	—	–
34. North Dakota		No	—		No	—	—	–	Yes			No
35. Ohio	xxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx
36. Oklahoma	Yes		1.5*		No	RDG	Yes		Yes		Yes	
37. Oregon	—	–	—	—	–	—	—	–	—	–	—	–
38. Pennsylvania		No	—	Yes		Varies		No		No		No
39. Rhode Island		No	—	Yes		RDG	Yes		Yes		Yes	
40. South Carolina	Yes		5.5	Yes		—	Yes			No	—	–
41. South Dakota	Yes		6	Yes		Varies	Yes			No	—	–
42. Tennessee	Yes		1.5		No	—	Yes			No	—	–
43. Texas	Yes		1.5*	Yes		10	Yes		Yes			No
44. Utah	Yes		1	Yes		RDG	Yes		Yes			No
45. Vermont	xxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx

State	Lateral Clear Zone Policy for Curbed Municipal Street			Lateral Clear Zone Policy for Non-Curbed Municipal Street			Policy Dependent on Concurrent Safety Improvement Project		Consideration for Shielded Poles for Relocation		Consider Using FHWA "UPACE" Economic Computer Model	
	Yes	No	Distance (ft)	Yes	No	Distance (ft)	Yes	No	Yes	No	Yes	No
46. Virginia	Yes		5.5	Yes		----	Yes		Yes		Yes	
47. Washington	Yes		2	Yes		10	Yes		Yes			No
48. West Virginia	Yes		2	Yes		6		No	Yes			No
49. Wisconsin	Yes		1.5	Yes		10-18		No	Yes		Yes	
50. Wyoming	No		RDG		No	RDG	----	--		No		--
51. Puerto Rico	xxx	xx	xxxx	xxx	xx	xxxx	xxx	xx	xxx	xx	xxx	xx

* - from face of curb
t - from edge of pavement
RDG - AASHTO "Roadside Design Guide"
YB - AASHTO Yellow Book
---- - answer left blank
xxxx - no response to questionnaire

TABLE 2.

Summary of Questionnaire #1 Responses

Response	Question No. #1	#2	#3	#4	#4(a)
Yes	31 (81.6%)	29 (80.6%)	29 (87.9%)	25 (67.6%)	9 (39.1%)
No	7 (18.4%)	7 (19.4%)	4 (12.1%)	12 (32.4%)	10 (43.5%)
Other	---	---	---	---	4 (17.4%)
Subtotal	**38**	**36**	**33**	**37**	**23**
Blank	5	7	10	6	20
No Response	8	8	8	8	8
Total	**51**	**51**	**51**	**51**	**51**
Average Distance (Ft)	3.375	10.269	---	---	---
Use Roadside Design Guide	3 States	9 States	---	---	---

Question #3:

This question sought to determine whether enforcement of lateral obstacle clear zone policies depended on planning for, or implementation of, concurrent safety improvements for a given roadway section. According to the summary presented in Table 2, 29 (87.9%) of the 33 states which responded to the question enforce the clear zone policy only when a concurrent safety improvement project is planned. Thus, lateral obstacle clear zone policies may not be enforced along the roadways unless some other safety improvement project is being implemented for a given location. For example, a city street may have utility poles located 1 ft behind the back of the curb but the minimum lateral offset for fixed objects may be 6 ft. The state might not find it feasible to relocate the line of utility poles to meet the minimum criteria unless it has been shown to be a safety improvement; usually this would be accomplished through a cost-effectiveness or a benefit-to-cost ratio analysis. Another possibility is that the state may not require the line of utility poles to be relocated unless some improvements to the geometrics of the roadway section are being made, for example, an improvement which involves lane widening. Apparently the reasoning is that since construction is already taking place along the given roadway section, the utility poles might as well be relocated at the same time.

Question #4:

The question sought to determine whether the state would even consider relocating a line of utility poles or luminaires that were located within the clear zone if they were partially shielded by trees. The data show that 25 (67.6%) of the 37 states that responded to the question would consider relating the partially shielded fixed objects; 12 (32.4%) of the states that responded would not even consider relocating the fixed objects (Table 2).

Even though the utility poles or luminaires may be partially shielded, a majority of the states must feel that some safety benefit may still be achieved. As stated earlier, this benefit is usually determined through an analysis which uses a cost-effectiveness or a benefit-to-cost ratio methodology.

Question #4(a):

The purpose of this question was to determine how many states would consider using the "UPACE" computer model in making the decision to relocate either utility poles or luminaires when they are partially shielded by trees. Respondents were asked to answer this question only if they had responded "YES" to Question 4. Nine (39.1%) of the 23 states that responded to this question stated they would consider using "UPACE"; 10 (43.5%) states stated they would not consider using the model, while 4 states responded that they were unfamiliar with the model (Table 2).

2.5 Other States' Lateral Obstacle Clear Zone Policies

States were also requested to send copies of their minimum design standards for lateral obstacle clear zone distances. These standared are presented in Table 3. A general classification system of standards in each of the fifty states plus Puerto Rico is presented in Table 4.

2.6 Summary

The review of lateral obstacle clear zone policies found that although individual states had established guidelines for locating utility facilities, policies varied widely according to roadway type, ADT, design speed, urban/rural environment, etc. There is no national standard for locating utility facilities.

The accident literature review is presented in the following chapter indicates the seriousness of fixed object accidents, and more specifically, utility and light pole accidents, along the roadways throughout the United States.

TABLE 3.

Minimum Design Standards for Lateral Obstacle Clear Zones

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
1. Alabama		No	
2. Alaska	Yes		(A) Low Speed Roadways (1) With Curbs - 2 ft from face of curb (2) Without Curbs - ADT < 750 7 ft - ADT > 750 10 ft (B) Intermediate Speed Roadways: 40 mph < x ≤ 50 mph (1) Urban - use criteria (A) except all curbs shall be mountable 2 ft from face of curb (2) Rural - use criteria (C) (C) High Speed Roadways: > 50 mph (1) Clear Roadside Concept
3. Arizona		No	Uses the AASHTO Publication, "Roadside Design Guide," 1989
4. Arkansas		No	Uses the AASHTO Publication, "A Policy on Geometric Design of Highways and Streets," 1984
5. California		No	
6. Colorado	Yes		(A) Local Rural Roads: (1) 10 ft from edge of traveled way (B) Local Urban Streets: (1) 2 ft from curb face or from edge of shoulder (2) ≤ 40 mph - 1.5 ft minimum - 2 ft preferred minimum - 3 ft minimum at intersections (C) Rural Collectors: (1) ≤ 40 mph - use criteria (A) (2) ≥ 50 mph - use the AASHTO Publication, "Guide for Selecting, Locating, and Designing Traffic Barriers," 1977 (3) 40 mph < x < 50 mph - use AASHTO 1977 (D) Urban Collectors and Arterials: (1) use AASHTO 1977 (2) use criteria (B) (2) (E) Rural Arterials: (1) use AASHTO 1977

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
7. Connecticut		No	Unavailable due to current revisions.
8. Deleware	Yes		(A) New Construction. (1) Two-Lane Highways (a) Rural Arterials and Collections - 10 ft to 30 ft (b) Urban Arterials and Collections - with shoulders 2 ft behind curb - without shoulders 6 ft behind curb (c) Local Roads - 10 ft to 15 ft (2) Multi-Lane Highways (a) Rural - 15 ft to 30 ft (b) Urban - with shoulders 2 ft to 30 ft behind curb - without shoulders 6 ft to 30 ft behind curb (B) 4R Improvements (1) Rural - use criteria (A) or install protection devices (2) Urban - 2 ft behind curb
9. Florida		No	
10. Georgia		No	Uses the AASHTO Publication, "A Policy on Geometric Design of Highways and Streets," 1984 and "Roadside Design Guide," 1989.
11. Hawaii		No	(A) Highways:* (1) Rural -30 ft from edge of roadway (2) Cities, Towns, and Urban Areas - With curbs 2 ft from face of curb - Without curbs 20 ft from edge of traveled way * - from Utility Accomodation Policy
12. Idaho	Yes		(A) Resurfacing, Restoration, and Rehabilitation (3R) Projects on Existing State and Local Highways: (1) Too detailed to summarize, see Section 14-703 of the Idaho Transportation Department's Design Manual (B) Resurfacing, Restoration, Rehabilitation, and Reconstruction (4R) Projects on the Interstate Highway System: (1) See Section 14-704 of the IDOT Design Manual (C) Federal-Aid Projects other than (3R) and (4R) Projects: (1) AASHTO Barrier Guide 1977 (2) AASHTO "Roadside Design Guide," 1989

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
13. Illinois	Yes		(A) Motor Fuel Tax (MFT) Policy: (1) Rural Highways - DHV > 200 23 ft from edge of pavement - DHV 100 - 200 20 ft from edge of pavement ADT 400 - 750 - ADT < 400 10 ft from edge of pavement (2) Urban Streets (a) ≤ 45 mph - with curbs 2 ft from face of curb - without curbs 10 ft (b) > 45 mph - use criteria (A) (1) (B) Federal Policy: (1) Rural Highways - varies with speed and roadway cross-section, but no less than 10 ft (2) Urban Streets - ≤ 45 mph 2 ft from face of curb - > 45 mph use criteria (B) (1) (C) 3R Policy: (1) Rural Cross-Sections - ≥ 50 mph 14 ft from edge of pavement - ADT > 1000 14 ft from edge of pavement - others 10 ft from edge of pavement (2) Urban Highways - 1.5 ft from face of curb - 1 ft may be considered
14. Indiana	Yes		(A) Rural and Urban Collectors (With Shoulders): (1) < 50 mph or ADT < 750 - 10 ft from edge of traffic lane or to right-of-way line, whichever is less (2) Other - 10 ft plus shoulder width or to right-of-way line, whichever is less (B) Rural and Urban Arterials (With Shoulders): (1) < 45 mph - 10 ft from edge of traffic lane or to right-of-way line, whichever is less (2) ≥ 45 mph - 20 ft or to right-of-way line, whichever is less (C) Roadways (With Curbs): (1) < 45 mph and Curb Height ≥ 6 in. - 1.5 ft from face of curb (2) ≤ 45 mph and/or Curb Height < 6 in. - see criteria (A) and (B)

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
15. Iowa		No	
16. Kansas		No	
17. Kentucky		No	
18. Louisiana		No	
19. Maine	Yes		(A) New Construction / Reconstruction (1) Rural - 30 ft from edge of travel lane (2) Urban (a) ≤ 35 mph - with curbs 1 ft from face of curb - without curbs 3 ft from edge of shoulder (b) > 35 mph - with curbs 3 ft from face of curb - without curbs 20 ft from edge of travel lane (B) Rehabilitation / Restoration (1) Rural - 30 ft from edge of travel lane (2) Urban (a) ≤ 35 mph - with curbs 1 ft from face of curb - without curbs 3 ft from edge of shoulder (b) > 35 mph - with curbs 2 ft from face of curb - without curbs 6 ft from edge of shoulder
20. Maryland	Yes		(A) Open Sections: (1) 30 mph 6 ft from edge of shoulder (2) 40 mph 9 ft from edge of shoulder (3) 50 mph 16 ft from edge of shoulder (4) 60 mph 20 ft from edge of shoulder (5) 70-80 mph 24 ft from edge of shoulder (B) Closed Sections: (1) Urban - 7 ft to 10 ft from face of curb (2) Suburban - 14 ft to 18 ft from face of curb
21. Massachusetts	Yes		(A) State Highways: (1) 12 ft from edge of traveled way (2) 6 ft from edge of traveled way

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
21. Mass, con't.			(B) New or Major Construction of Rural Arterial Roadways: (1) 40 mph 18 ft from edge of travel lane (2) 50 mph 24 ft from edge of travel lane (3) 60 ph 30 ft from edge of travel lane (4) 70 mph 30 ft from edge of travel lane (C) 3R Projects: (1) Rural - > 50 mph 30 ft from edge of travel lane (2) Urban - < 50 mph behind sidewalk
22. Michigan		No	
23. Minnesota		No	
24. Mississippi	Yes		(A) Rural Arterials: (1) Two-Lane - ADT < 499 22 ft from edge of travel lane - ADT ≥ 400 22 ft from edge of travel lane DHV 100 - 200 - DHV 201 - 400 26 ft from edge of travel lane - DHV > 400 26 ft from edge of travel lane (2) Multi-Lane - 30 ft from edge of travel lane (B) Rural Collectors: (1) ADT < 400 20 ft from edge of travel lane (2) ADT ≥ 400 20 ft from edge of travel lane DHV 100 - 200 (3) DHV 201 - 400 22 ft from edge of travel lane (4) DHV > 400 26 ft from edge of travel lane (C) Urban Arterials: (1) Two-Lane (a) With Curbs - 1.5 ft from face of curb (b) Without Curbs - 40 mph 16 ft from edge of travel lane - 50 mph 22 ft from edge of travel lane (2) Multi-Lane (a) With Curbs - 1.5 ft from face of curb (b) Without Curbs - 40 mph 18 ft from edge of travel lane - 50 mph 24 ft from edge of travel lane - 60 mph 26 ft from edge of travel lane

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
24. Miss. con't.			(D) Urban Collector Streets: (1) With Curbs - 1.5 ft from face of curb (2) Without Curbs - 30 mph 10 ft from edge of travel lane - 40 mph 14 ft from edge of travel lane (E) Urban Local Streets: (1) With Curbs - 1.5 ft from face of curb (2) Without Curbs - 10 ft from edge of travel lane
25. Missouri	Yes		(A) Luminaires and Poles: (1) 30 ft mounting height 4 ft from edge of shoulder (2) 45 ft mounting height 5 ft from edge of shoulder
26. Montana	Yes		(A) Rural: (1) 30 ft from edge of outside travel lane (B) Urban: (1) 2 ft from face of curb
27. Nebraska	Yes		(A) New and Reconstructed Rural State Highways: (1) Interstate - 30 ft from edge of driving lane (2) Expressway or Major Arterial - DHV > 750 30 ft from edge of driving lane - DHV 330-750 30 ft from edge of driving lane - ADT 1700-3000 30 ft from edge of driving lane - ADT 850-1700 23 ft from edge of driving lane - ADT 400 - 850 22 ft from edge of driving lane - ADT < 400 20 ft from edge of driving lane (B) Resurfacing, Restoration, and Rehabilitation (3R) Projects on Non-Interstate Rural State Highways: (1) ADT > 3000 30 ft from edge of driving lane (2) ADT 1700 - 3000 20 ft from edge of driving lane (3) ADT 400 - 1700 12 ft from edge of driving lane (4) ADT < 400 12 ft from edge of driving lane

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
27. Nebraska, con't.			(C) Scenic - Recreation - Rural State Highways: (1) DHV > 750 - Desirable 30 ft from edge of driving lane - Minimum 12 ft from edge of driving lane (2) DHV 400 - 750 - Desirable 30 ft from edge of driving lane - Minimum 12 ft from edge of driving lane (3) DHV 200 - 400 - Desirable 20 ft from edge of driving lane - Minimum 10 ft from edge of driving lane (4) ADT 850 - 1700 - Desirable 12 ft from edge of driving lane - Minimum 8 ft from edge of driving lane (5) ADT < 850 - Desirable 12 ft from edge of driving lane - Minimum 6 ft from edge of driving lane (D) New and Reconstructed Municipal State Highways: (1) Interstate - 30 ft from edge of driving lane (2) Arterials and Collectors (a) With Curbs - 6 ft from back of curb (b) Without Curbs - ≤ 45 mph 15 ft from edge of driving lane - ≥ 50 mph see criteria (A) (E) Resurfacing, Restoration, and Rehabilitation (3R) Projects on Non-Interstate Municipal State Highways: (1) With Curbs - 2 ft from back of curb (2) Without Curbs - <_ 45 mph 10 ft from edge of driving lane - >_ 50 mph see criteria (B) (F) Municipal Streets: (1) With Curbs - 2 ft from back of curb (2) Without Curbs - 8 ft from edge of driving lane (G) Rural Roads: (1) Arterial - ADT 401 - 750 12 ft - ADT 251 - 400 10 ft - ADT 51 - 250 10 ft - ADT 0 - 50 9 ft

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
27. Nebraska, con't.			(2) Collector - ADT 251 - 400 10 ft - ADT 51 - 250 10 ft - ADT 0 - 50 Shoulder + 2 ft (3) Local - ADT 0 - 400 Shoulder + 2 ft (4) or see criteria (F) (H) Scenic - Recreation - Rural Roads: (1) Arterial - ADT 401 - 750 10 ft - ADT 251 - 400 10 ft - ADT 0 - 250 9 ft (2) Collector - ADT 251 - 400 10 ft - ADT 0 - 250 Shoulder + 2 ft (3) Local - ADT 0 - 400 Shoulder + 2 ft (4) or see criteria (F)
28. Nevada		No	
29. New Hampshire	Yes		(A) Interstate Highways and Major Arterials: (1) 30 ft from edge of traveled way (B) State Highways: (1) With Curbs - 5 ft (2) Without Curbs - 8 ft from edge of paved surface (C) Urban Conditions (1) 1.5 ft from face of curb (2) 2 ft from face of curb with continuous parking
30. New Jersey	Yes		(A) Rural and Urban Highways: (1) 25 mph 9 ft from edge of traveled way (2) 30 mph 11 ft from edge of traveled way (3) 35 mph 13 ft from edge of traveled way (4) 40 mph 15 ft from edge of traveled way (5) 45 mph 17 ft from edge of traveled way (6) 50 mph 20 ft from edge of traveled way (7) 55 mph 25 ft from edge of traveled way (8) 60 mph 30 ft from edge of traveled way (9) 70 mph 36 ft from edge of traveled way (B) Urban Arterials, Collectors, and Local Streets: (1) 1.5 ft from face of curb
31. New Mexico		No	Uses the AASHTO Publication, "Roadside Design Guide," 1989
32. New York		No	

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
33. North Carolina	Yes		(A) Conventional Highways in Urban Areas: (1) With Curbs and No Sidewalks - 6 ft (B) Federal-Aid Projects: (1) ≤ 35 mph - 6 ft offset behind curb - 10 ft offset from edge of travel way (2) 35 mph < x < 55 mph - 20 ft offset (3) ≥ 55 mph - 25 ft offset (4) Intersections with Large Radii - see diagrams in the NCDOT Utility Manual (C) Other (1) AASHTO 1977 (2) NCDOT Guidelines for Planting within Highway Right-of-Way" (3) NCDOT "Roadway Design Manual"
34. North Dakota		No	
35. Ohio		No	
36. Oklahoma	Yes		(A) Rural Highways: (1) Principal Arterials, Minor Arterials, and State Major Collectors (a) Federal-Aid Projects - use current AASHTO Guidelines (b) SAP Projects - outside edge of shoulder plus 3 ft (B) Urban or Municipal Highways: (1) Principal Arterials - With Curbs 6 ft - Without Curbs outside edge of shoulder (2) Minor Arterials and Collectors (a) ADT 0 - 180 - 2 ft minimum - 6 ft desirable (b) ADT 180 - 600 - 2 ft minimum - 6 ft desirable (c) ADT > 600 - 6 ft

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
36. Okla., con't.			(C) Common ODOT Practices (1) With Curbs - 1.5 ft minimum - 8 ft desirable - 5 ft at signal poles standard (2) Without Curbs - Low Speed 10 ft Desirable - High Speed "Roadside Design Guide"
37. Oregon		No	
38. Pennsylvania		No	
39. Rhode Island		No	Uses the AASHTO Publication, "Roadside Design Guide," 1989
40. South Carolina		No	
41. South Dakota	Yes		(A) Two-Lane Rural Arterial Highways: (1) Principal (a) Major Reconstruction / New Construction - ADT < 1000 30 ft - ADT 1000 - 1500 30 ft - ADT > 1500 30 ft (b) Minor Reconstruction - ADT < 1000 25 ft - ADT 1000 - 1500 30 ft - ADT > 1500 30 ft (c) Resurfacing - ADT < 1000 20 ft - ADT 1000 - 1500 20 ft - ADT > 1500 20 ft (2) Minor (a) Major and Minor Reconstruction / New Construction - ADT < 500 25 ft - ADT 500 - 1000 30 ft - ADT > 1000 30 ft (b) Resurfacing - ADT < 500 20 ft - ADT 500 - 1000 20 ft - ADT > 1000 20 ft (B) Two-Lane Rural Collector Roads: (1) Major Reconstruction / New Construction - ADT < 250 20 ft - ADT 250 - 500 25 ft - ADT > 500 30 ft

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
41. S. Dakota, con't.			(2) Minor Reconstruction - ADT < 250 20 ft - ADT 250 - 500 20 ft - ADT > 500 25 ft (3) Resurfacing - ADT < 250 10 ft - ADT 250 - 500 15 ft - ADT > 500 20 ft (C) Arterial Streets: (1) 30 mph 2 ft (2) 40 mph 6 ft (3) 50 mph 6 ft (4) 60 mph 8 ft (D) Major Collector Streets: (1) 2 ft (2) 8 ft desirable
42. Tennessee		No	
43. Texas	Yes		(A) Rural:* (1) Freeways - 30 ft minimum (2) Arterial (a) ADT < 750 - 10 ft minimum - 16 ft desirable (b) ADT 750 - 1500 - 16 ft minimum - 30 ft desirable (c) ADT ≥ 1500 - 30 ft minimum (3) Collector - ≥ 45 mph see criteria (A) (1) - ≤ 40 mph 10 ft minimum (4) Local - 10 ft minimum (B) Urban:* (1) Freeways - 30 ft minimum (2) With Curbs (a) ≤ 45 mph - 1.5 ft minimum from face of curb - 3 ft desirable from face of curb (b) ≥ 50 mph - see criteria (A) (2)

STATE	Minimum Design Standards Sent		Minimum Design Standards
	Yes	No	
43. Texas, con't.			(3) Without Curbs - ≤ 40 mph 10 ft minimum - ≥ 45 mph see criteria (A) (2) * - All non-curbed section distances are measured from the edge of travel lane.
44. Utah		No	Uses the AASHTO Publication, "Roadside Design Guide," 1989
45. Vermont		No	
46. Virginia	Yes		Since the standards were too detailed to summarize, one should obtain them from the Virginia Department of Transportation.
47. Washington	Yes		Lateral clearance values are given in Chapter 710 of Washington's Design Standards which were not supplied.
48. West Virginia		No	
49. Wisconsin	Yes		(A) Rural Highways: (1) ADT < 1500 10 ft from edge of traffic lane (2) ADT > 1500 18 ft from edge of traffic lane (B) Urban and Suburban Roadway With Shoulders: (1) ≤ 45 mph 10 ft from edge of traffic lane (2) > 45 mph 18 ft from edge of traffic lane (C) Curbed Roadways: (1) ≤ 45 mph 1.5 ft from face of curb (2) > 45 mph see criteria (A)
50. Wyoming		No	Uses the AASHTO Publiction, "Roadside Design Guide," 1989
51. Puerto Rico		No	

Table 4. Generalized Classification for All State's Minimum Design Standards

RURAL AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																
	AL	AK	AZ	AR	CA	CO	CT	DE	FL	GA	HI	ID	IL	IN	IA	KS	KY
I. Freeways- Arterials (>55mph)																	
A. With Curb																	
1. Low ADT								2-6						10			
2. Medium ADT								2-6						10			
3. High ADT								2-6						10			
B. Without Curb																	
1. Low ADT								10-30						20			
2. Medium ADT								10-30						20			
3. High ADT								10-30						20			
II. Collectors - Highways (35-55 mph)																	
A. With Curb																	
1. Low ADT		2						2-6			30						
2. Medium ADT		2						2-6			30						
3. High ADT		2						2-6			30						
B. Without Curb																	
1. Low ADT		7				10		10-30			30		10	10			
2. Medium ADT		7				10		10-30			30		20	10			
3. High ADT		10				10		10-30			30		20-23	10			

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

RURAL AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																
	AL	AK	AZ	AR	CA	CO	CT	DE	FL	GA	HI	ID	IL	IN	IA	KS	KY
III. Local-Residential (<35mph)																	
A. With Curb																	
1. Low ADT		2						10-15						1.5			
2. Medium ADT		2						10-15						1.5			
3. High ADT		2						10-15						1.5			
B. Without Curb																	
1. Low ADT		7				10		10-15									
2. Medium ADT		7				10		10-15									
3. High ADT		10				10		10-15									
IV. AASHTO Guidelines																	
A. Roadside Design Guide 1989			*							*		*					
B. Geometric Design of Highways and Streets 1984				*						*							
C. Barrier Guide 1977						*						*					
V. Information Not Available	NA				NA		NA		NA						NA	NA	NA

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

RURAL AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)															
	LA	ME	MD	MA	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY	NC
I. Freeways- Arterials (>55mph)																
A. With Curb																
1. Low ADT																
2. Medium ADT																
3. High ADT																
B. Without Curb																
1. Low ADT		30	20-24	24-30			22		30	20		30				
2. Medium ADT		30	20-24	24-30			22		30	22		30				
3. High ADT		30	20-24	24-30			22		30	23		30				
II. Collectors - Highways (35-55 mph)																
A. With Curb																
1. Low ADT												5				
2. Medium ADT												5				
3. High ADT												5				
B. Without Curb																
1. Low ADT		30	9-16	6-12			20		30	12		8	13-20			
2. Medium ADT		30	9-16	6-12			20		30	12		8	13-20			
3. High ADT		30	9-16	6-12			20		30	12		8	13-20			

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

RURAL AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)															
	LA	ME	MD	MA	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY	NC
III. Local-Residential (<35mph)																
A. With Curb																
1. Low ADT																
2. Medium ADT																
3. High ADT																
B. Without Curb																
1. Low ADT		30	6						30							
2. Medium ADT		30	6						30							
3. High ADT		30	6						30							
IV. AASHTO Guidelines																
A. Roadside Design Guide 1989														*		
B. Geometric Design of Highways and Streets 1984																
C. Barrier Guide 1977																
V. Information Not Available	NA				NA	NA		NA			NA				NA	NA

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

RURAL AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																	
	ND	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI	WY	PR
I. Freeways- Arterials (>55mph)																		
A. With Curb																		
1. Low ADT																		
2. Medium ADT																		
3. High ADT																		
B. Without Curb																		
1. Low ADT								20-30		10								
2. Medium ADT								20-30		16								
3. High ADT								20-30		30								
II. Collectors - Highways (35-55 mph)																		
A. With Curb																		
1. Low ADT			2													10		
2. Medium ADT			2													10		
3. High ADT			6													18		
B. Without Curb																		
1. Low ADT			2					20		10						10		
2. Medium ADT			2					25		10						10		
3. High ADT			6					30		10						18		

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

RURAL AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																	
	ND	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI	WY	PR
III. Local-Residential (<35mph)																		
A. With Curb																		
1. Low ADT			1.5					2		10						1.5		
2. Medium ADT			1.5					2		10						1.5		
3. High ADT			1.5					2		10						1.5		
B. Without Curb																		
1. Low ADT																		
2. Medium ADT																		
3. High ADT																		
IV. AASHTO Guidelines																		
A. Roadside Design Guide 1989						•					•						•	
B. Geometric Design of Highways and Streets 1984																		
C. Barrier Guide 1977																		
V. Information Not Available	NA	NA		NA	NA		NA		NA			NA	NA	NA	NA			NA

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

URBAN AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																
	AL	AK	AZ	AR	CA	CO	CT	DE	FL	GA	HI	ID	IL	IN	IA	KS	KY
I. Freeways- Arterials (>55mph)																	
A. With Curb																	
1. Low ADT								2-6			2			20			
2. Medium ADT								2-6			2			20			
3. High ADT								2-6			2			20			
B. Without Curb																	
1. Low ADT											20			20			
2. Medium ADT											20			20			
3. High ADT											20			20			
II. Collectors - Highways (35-55 mph)																	
A. With Curb																	
1. Low ADT		2				1.5-3		2-30			2		2	1.5			
2. Medium ADT		2				1.5-3		2-30			2		2	1.5			
3. High ADT		2				1.5-3		2-30			2		2	1.5			
B. Without Curb																	
1. Low ADT											20		10	10			
2. Medium ADT											20		10	10			
3. High ADT											20		10	10			

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

URBAN AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																
	AL	AK	AZ	AR	CA	CO	CT	DE	FL	GA	HI	ID	IL	IN	IA	KS	KY
III. Local-Residential (<35mph)																	
A. With Curb																	
1. Low ADT		2				1.5-3		10-15			2		2	1.5			
2. Medium ADT		2				1.5-3		10-15			2		2	1.5			
3. High ADT		2				1.5-3		10-15			2		2	1.5			
B. Without Curb																	
1. Low ADT		7									20		10				
2. Medium ADT		7									20		10				
3. High ADT		10									20		10				
IV. AASHTO Guidelines																	
A. Roadside Design Guide 1989			*							*		*					
B. Geometric Design of Highways and Streets 1984				*						*							
C. Barrier Guide 1977												*					
V. Information Not Available	NA				NA		NA		NA						NA	NA	NA

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

URBAN AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)															
	LA	ME	MD	MA	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY	NC
I. Freeways- Arterials (>55mph)																
A. With Curb																
1. Low ADT		3	7-10				1.5		2				1.5			
2. Medium ADT		3	7-10				1.5		2				1.5			
3. High ADT		3	7-10				1.5		2				1.5			
B. Without Curb																
1. Low ADT		20					16-22			30		30				
2. Medium ADT		20					16-22			30		30				
3. High ADT		20					16-22			30		30				
II. Collectors - Highways (35-55 mph)																
A. With Curb																
1. Low ADT		3	7-10				1.5		2	6		5	1.5			6
2. Medium ADT		3	7-10				1.5		2	6		5	1.5			6
3. High ADT		3	7-10				1.5		2	6		5	1.5			6
B. Without Curb																
1. Low ADT		20		6-12			10-14			15		8	13-20			
2. Medium ADT		20		6-12			10-14			15		8	13-20			
3. High ADT		20		6-12			10-14			15		8	13-20			

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

URBAN AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)															
	LA	ME	MD	MA	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY	NC
III. Local-Residential (<35mph)																
A. With Curb																
1. Low ADT		1	7-10				1.5		2	2		1.5	1.5			
2. Medium ADT		1	7-10				1.5		2	2		1.5	1.5			
3. High ADT		1	7-10				1.5		2	2		1.5	1.5			
B. Without Curb																
1. Low ADT		3					10			8						
2. Medium ADT		3					10			8						
3. High ADT		3					10			8						
IV. AASHTO Guidelines																
A. Roadside Design Guide 1989														*		
B. Geometric Design of Highways and Streets 1984																
C. Barrier Guide 1977																
V. Information Not Available	NA				NA	NA		NA			NA				NA	

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

URBAN AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																	
	ND	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI	WY	PR
I. Freeways- Arterials (>55mph)																		
A. With Curb																		
1. Low ADT			6															
2. Medium ADT			6															
3. High ADT			6															
B. Without Curb																		
1. Low ADT										30						18		
2. Medium ADT										30						18		
3. High ADT										30						18		
II. Collectors - Highways (35-55 mph)																		
A. With Curb																		
1. Low ADT			2							1.5						1.5		
2. Medium ADT			2							1.5						1.5		
3. High ADT			2							1.5						1.5		
B. Without Curb																		
1. Low ADT			2							10						18		
2. Medium ADT			2							16						18		
3. High ADT			6							30						18		

Table 4. Generalized Classification for All State's Minimum Design Standards, con't.

URBAN AREAS	STATE'S MINIMUM DESIGN STANDARDS (ft.)																	
	ND	OH	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI	WY	PR
III. Local-Residential (<35mph)																		
A. With Curb																		
1. Low ADT			1.5							1.5						1.5		
2. Medium ADT			1.5							1.5						1.5		
3. High ADT			1.5							1.5						1.5		
B. Without Curb																		
1. Low ADT										10						10		
2. Medium ADT										10						10		
3. High ADT										10						10		
IV. AASHTO Guidelines																		
A. Roadside Design Guide 1989						*					*						*	
B. Geometric Design of Highways and Streets 1984																		
C. Barrier Guide 1977																		
V. Information Not Available	NA	NA		NA	NA		NA	NA	NA			NA	NA	NA	NA			NA

3 ACCIDENT LITERATURE REVIEW

A number of research studies have addressed accidents involving fixed objects, specifically, utility and light poles. In this chapter relevant national accident data and statistical information are presented and some recent studies involving fixed objects are reviewed.

According to the National Safety Council (NSC), 48,700 motor-vehicle deaths and 1,800,000 disabling injuries occurred nationwide in 1987 (1). The total cost was estimated at approximately $64.7 million. Nationwide, there were 43,300 fatal accidents, 1,200,000 injury accidents, and 19,600,000 property-damage-only accidents (PDO's). Collisions with fixed objects accounted for a significant portion of these incidents: 3,400 out of the 48,700 deaths and 70,000 out of the 1,800,000 disabling injuries. From 1985-1987, 9.5% of the fatal accidents and 4.8% of all accidents resulted from a collision with a fixed object. The problem of collisions with fixed objects is more pronounced in urban areas where the figures are 13.5% and 5.4%, respectively, as compared to 7.3% and 3.5% in rural areas. Reports from three traffic authorities indicate that the most frequent type of fixed object accident involved a collision with trees or shrubbery, and accounted for 22.3% of fatal accidents and 17.3% of injury accidents (Table 5). Collisions with utility poles were most common, occurring in 13.5% of all accidents, or 17.7% if light supports are included.

According to the National Highway Traffic Safety Administration (NHTSA), 46,386 fatalities resulted from 41,435 fatal accidents in 1987 (2). Of the 25,833 first-harmful-event, single-vehicle accidents, 12,499 deaths (48.4%) occurred from collisions with a fixed object such as a tree, utility pole, sign, guardrail, stationary structure, or substantial vegetation.

TABLE 5

Type of Fixed Object Struck by Accident Severity, 1987

Type of Fixed Object	Severity of Accident			
	Fatal Accidents	Injury Accidents	Property Damage Accidents	All Accidents
Total	100.0%	100.0%	100.0%	100.0%
Tree, shrubbery	22.3	17.3	10.6	13.0
Embankment	13.7	15.3	9.8	11.7
Utility Pole	13.2	15.9	12.2	13.5
Guardrail post	10.9	7.8	7.5	7.6
Fence	7.4	8.3	14.9	12.6
Culvert, ditch or abutment	6.9	1.6	1.3	1.4
Light support	4.0	4.6	4.0	4.2
Rock, ledge	4.0	3.2	2.0	2.4
Median, curb	2.8	3.7	5.9	5.1
Bridge, pier	2.3	2.1	2.1	2.1
Sign post	2.3	2.6	4.9	4.1
Building, wall	1.7	3.3	3.6	3.5
Barricade	1.1	1.3	1.1	1.2
Impact attenuator, crash cushion	0.0	0.2	0.3	0.3
Other fixed object	7.4	12.8	19.8	17.3

Source: Based on reports from 3 state traffic authorities.

In 1987, 28.5% of fatal accidents and 27.9% of fatalities resulted from a fixed-object collision as recorded by first harmful event.

On Nebraska roadways in 1987, there were 255 fatal accidents (0.7%), 14,567 injury accidents (38.%), and 23,248 PDO's (61.1%), which resulted in 297 fatalities and 21,917 injuries (3). For all accidents and fatal accidents by first harmful event, 12% and 23%, respectively, involved a collision with a fixed object.

Gustafson reported that nationwide from 1982 to 1984, 5,600 fatal accidents involving utility poles or light supports resulted in 6,046 deaths (4). From 1977 to 1983, 16,720 Iowa accidents involving utility poles or light poles resulted in 124 fatal accidents, 5,754 injury accidents, and 10,842 PDO's; resulting in 137 deaths and 7,760 injuries.

From a limited study in 1972, Graf, Boos, and Wentworth estimated that utility pole accidents account for more than 5% of the national traffic fatalities annually and more than 15% of the fixed object traffic fatalities (5). They estimated that utility pole accidents account for 2,750 fatalities, 110,000 injuries, and 250,000 PDO's annually.

A study by Fox, Good, and Joubert in Australia investigated a total of 879 pole accidents occurring between July 7, 1976 and March 7, 1977 (6). The distribution by accident severity was 3% fatal accidents, 27% injury accidents, and 70% PDO's. In 1976, pole collisions resulted in 54 fatalities (5.8%) and 813 injuries (4.6%) in the State of Victoria. The corresponding figures for the Melbourne metropolitan area were 45 fatalities (9.4%) and 785 injuries (5.9%).

In 1978, Post, McCoy, Wipf, Bolton, and Mohaddes found that wooden utility poles have a higher-than-average accident severity than fixed objects located along streets in urban areas statewide (7). In 1978, 291 utility pole accidents were noted in Lincoln, Nebraska, with a corresponding accident severity of 0%, 45%, and 55%, for fatalities, personal injuries, and PDO's, respectfully. Statewide, the corresponding accident severity for fixed object collisions in urban areas was 1%, 35%, and 64%, respectively.

Nationwide, Labra and Michie found vehicle impacts with wooden utility poles to have the highest frequency of severe and fatal injuries to occupants of all single-vehicle incidents (8). Utility pole accidents were four times more likely to result in fatalities than all other accidents: over 8,300 deaths occurred in 4,400 utility pole accidents from 1975 to 1977.

Jones and Baum reported that utility pole accidents were by far the most frequent, accounting for 21.1% of all fixed objects struck for single-vehicle, first object struck accidents, as shown in Table 6; they also account for 2.2% of all accidents in urban areas (9). Utility poles were found to have the second highest percentage of injury (50.5%) with the exception of vehicles striking the ground (52.6%), which generally were rollover type accidents, as shown in Table 7.

TABLE 6
First Object Struck in Single Vehicle Accidents Ranked by Frequency

First Object Struck	Number of Accidents	Percentage of Total
Utility Pole	1291	21.1
Fence, Guardrail	825	13.5
Sign, Mailbox, Parking Meter, Guy Wire	728	11.9
Culvert, Ditch, Embankment	714	11.7
Tree	682	11.1
Light, Signal Pole	466	7.6
Fire Hydrant	223	3.6
Building	215	3.5
Ground (generally rollover)	187	3.1
Wall	175	2.9
Shrubbery	120	2.0
Bridge	116	1.9
None	79	1.3
Other	303	4.9
Total	6124	100.0

Pilkington stated that the utility pole accident is the most frequent and severe roadside accident involving a "man-made" object (10): it is six times more likely to result in a fatality and three times more likely to result in an injury than the average roadway accident. The driver is most often injured, while a front seat passenger is most likely to become a fatality. An estimated 80% of utility pole accidents are frontal impacts resulting in injuries. Approximately 20% of utility pole accidents result in a side impact fatality. It is also estimated that there are approximately 88 million utility poles located along our streets and highways. According to Pilkington, a considerable number of utility pole accidents are not reported since vehicle damage is often minor and drivers leave the seen. However, the poles are often significantly damaged and require repair or replacement.

TABLE 7

Relative Severity of Different Objects Struck

Object	Total* Accidents	Injury Accidents	% Injury Accidents	% of Total Injury Accidents
Utility Pole	1166	589	50.5	31.4
Fence, Guardrail	740	171	23.1	9.1
Sign, Parking Meter, Mail box, Guy Wire	668	133	19.9	7.1
Culvert, Ditch, Embankment	674	300	44.5	16.0
Tree	598	257	43.0	13.7
Light, Signal Pole	365	77	21.1	4.1
Fire Hydrant	179	32	17.9	1.7
Building	163	33	21.2	1.8
Ground (generally rollover)	175	92	52.6	4.9
Wall	147	53	36.1	2.8
Shrubbery	100	7	7.0	0.4
Bridge	115	47	40.9	2.5
None	79	12	15.2	0.6
Other	202	72	35.6	3.8
Total	5371	1875	34.9	100.0

*Excludes those where injury was unknown

Mak and Mason performed an extensive study on pole accidents between 1975 and 1980 (11). Accident data was initially obtained from only two sample areas; the number of study areas was later expanded to seven in order to obtain more data. They found that while reported pole accidents accounted for 3.3% of all accidents reported in the two original study areas, pole accidents accounted for 20.6% of all accidents and 9.9% of all injury accidents with respect to severity. Thus, pole accidents were found to be six times more likely to result in fatalities and three times more likely to result in injuries than all other accidents. Utility poles were the most frequently struck pole type, accounting for 67.1% of all pole accidents, followed by sign supports and luminaires at 16% and 14.4%, respectively.

Mak and Mason found that pole accident sites have a higher pole density and are located closer to the roadway (11). In urban areas, accident sites have 120 poles per mile and a median lateral offset of 5.2 feet compared with 80 poles per mile and 6.7 feet for average sites. In rural areas, accident sites have 56 poles per mile and a median lateral offset of 8.7 feet compared with 22 poles per mile and 11.8 feet for average sites. Pole accidents in rural areas were found to have a higher injury severity than urban pole accidents due to higher impact speeds.

In terms of frequency of severe to fatal injuries, Mak and Mason (11) reported that collisions with timber utility poles have the highest frequency at 7.4%, followed by nonbreakaway and breakaway luminaires at 4.9% and 3.8%, respectively. In terms of overall severity, nonbreakaway luminaires and timber utility poles have the highest frequencies at 72.4% and 66.8%, respectively. Collisions with other pole types result in smaller frequencies of overall injury occurring at less than 40%.

The extensive human and economic costs associated with accidents involving fixed objects motivate national and state government efforts to establish policy governing their use. In the next chapter a literature review is presented of national and state government policy for accomodating facilities. The purpose of the review is to present the range of accommodation policies and standards to which the utility or light poles must conform.

4 GOVERNMENTAL POLICY LITERATURE REVIEW

4.1 Introduction

Policies and standards for accomodating utilities are set at several levels of government. The sections which follow describe the current guidelines provided by the State of Nebraska, by AASHTO, and by the Federal Government.

4.2 State of Nebraska Policy

The following section summarizes Nebraska state policies and standards for accommodating utilities.

Responsibility

Nebraska policy states (12):

> The State of Nebraska, Department of Roads has the responsibility to regulate utility occupancy on all State highways. The Department of Roads may enter into agreement with qualified Political Subdivisions to provide for exercising this responsibility on certain State highways within the geographical boundaries of the Political Subdivisions. All other public highways not designated as State highways are under the authority of the cities and counties wherein such road lies. These Political Subdivisions exercise authority over utility occupancy of these public roads in accordance with State law and local ordinances.
>
> Utilities are permitted to occupy public highway right-of-way under Nebraska Statutes and in accordance with the Rules and Regulations of the authority having jurisdiction over the highway.
>
> It is the intent of this policy to incorporate all of the provisions of Federal Highway Administration FHPM 6-6-3-2 and the AASHTO publications "A Policy on the Accommodation of Utilities on Freeway Right-of-Way" and "A Guide for Accommodating Utilities on Highway Right-of-Way" which are not in conflict with the provisions of this policy.

Definition of Terms

Some of the relevant terms used in the State of Nebraska policy are defined as follows (12):

clear roadside policy:

The policy employed by a highway authority to increase safety, improve traffic operation, and enhance the appearance of highways by designing, constructing, and maintaining highway roadsides as wide, flat, and rounded as practical and as free as practical from physical obstructions above the ground such as trees, drainage structures, massive sign supports, utility poles, and other ground-mounted obstructions.

traveled way:

The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxilliary lanes.

utility:

Shall mean and include all privately, publicly or cooperatively owned lines, facilities and systems for producing, transmitting or distributing communications, power, electricity, light, heat, gas, chemicals, oil, crude, products, water, steam, waste, storm water not connected with highway drainage, and other similar commodities, including publicly owned fire and police signal systems and street lighting systems, which directly or indirectly serve the public or any part thereof. The term "utility" shall also mean the utility company, inclusive of any wholly owned or controlled subsidiary.

Specifications

Overhead electrical and communication lines located within the public highway right-of-way shall comply with the current National Electric Safety Code (13). Joint use of utility poles also is encouraged to avoid locating additional poles within the right-of-way.

The general specifications for the horizontal clearance for ground-mounted utility facilities are described as follows (12):

(A) Rural areas: All rigid poles must be located at least thirty (30) feet or more from the edge of the traveled way.

(1) Poles and anchors will be permitted to occupy the outer two (2) feet of the highway Right-of-Way on highways without sufficient Rights-of-Way to permit pole lines to comply with Subsection (A).

(B) Urban or suburban areas where the highway speed limits are forty-five (45) mph or lower and the highway cross-section is constructed to a typical rural cross-section standard (i.e., open ditches, shoulders, and highway resurfacing): All rigid poles shall be located at least fifteen (15) feet from the edge of the traveled way and the preferred location is near the right-of-way line.

(C) Cities, towns, and urban areas where curb sections exist: Rigid poles may be located back of the sidewalk or a minimum of six (6) feet back of the curb where feasible.

(D) Exceptions to these clearances may be made where curbside parking is permitted or where poles and anchors can be placed at locations behind guard rails, beyond deep ditches or on top of high banks, or other similar locations that would not present additional hazards to the traveling public.

When feasible, poles located closer than the limits defined in paragraphs B, C, and not covered in paragraph D must contain frangible bases or breakaway features to allow the pole to collapse when impacted.

The Nebraska Department of Roads currently uses the document entitled, "Minimum Design Standards," to provide detailed specifications for the lateral obstacle clearance distance (14). The Nebraska Department of Roads has eight roadway classifications for which there are different lateral obstacle policies. The eight roadway classifications are:

(1) New and Reconstructed Rural State Highways
(2) Resurfacing, Restoration, and Rehabilitation (3R) Projects on Non-Interstate Rural State Highways
(3) Scenic - Recreation - Rural State Highways
(4) New and Reconstructed Municipal State Highways
(5) Resurfacing, Restoration, and Rehabilitation (3R) Projects on Non-Interstate Municipal State Highways
(6) Municipal Streets
(7) Rural Roads
(8) Scenic - Recreation - Rural Roads

Appendix B provides the design standards for lateral obstacle clearance on the various roadway classifications as provided by the State of Nebraska (14).

4.3 AASHTO Policy

The American Association of State Highway and Transportation Officials (AASHTO) currently has two major publications which address accommodation of utilities, "A Guide for Accommodating Utilities Within Highway Right-of-Way" (15) and "A Policy on the Accommodation of Utilities Within Freeway Right-of-Way" (16). Because the AASHTO policy which pertains to freeway right-of-way is not significant to this study, a summary of the statement on highway right-of-way is provided. The following section summarizes the relevant sections of AASHTO guide (15).

Responsibility

The AASHTO guide states:

> Each highway agency has the responsibility to maintain the right-of-way of highways under its jurisdiction as necessary to preserve the operational safety, integrity, and function of the highway facility. Since the manner in which utilities cross or otherwise occupy highway right-of-way can materially affect the safe operation, maintenance, and appearance of the highway, it is necessary that such use and occupancy be authorized and reasonably regulated. The highway agencies have various degrees of authority to designate and to control the use made of right-of-way acquired for public highway purposes. Their authorities depend upon State laws or regulations, which differ between States. A State also may have local city or county government laws and regulations which differ from those applicable State-wide for highways.
>
> Utilities also have various degrees of authority to install their lines and facilities on the right-of-way of public roads and streets. Like highway agencies, their authorities depend upon State laws and regulations which differ between States. They also depend upon franchises, local laws, and ordinances which differ in the several political subdivisions within a State.
>
> Aside from the necessary differences imposed by State and local laws , regulations, franchises, governmental and industry codes, climate, geography, there can be and should be reasonable uniformity in the engineering requirements employed by highway agencies for regulating utility use of highway right- of-way. In this respect, guidelines outlining safe rational practices for accommodating utilities within highway right-of-way are of

valuable assistance to the highway agencies. The guidelines herein are provided in the interest of developing and preserving safe operations and roadsides and of minimizing possible interference and impairment to the highway, its structures, appearance, and maintenance.

These guidelines make no reference to the legal rights of utilities to use or occupy highway right-of-way or to reimbursement of utility owners for the cost of adjusting or installing utilities on such right-of-way. These matters are governed by State law. These guidelines should be interpreted and applied to the extent consistent with State laws which give utilities the right to use or occupy highway right-of-way.

It is the intent of these guidelines to assist the various highway agencies in establishing and administering reasonably uniform utility accommodation policies.

Wherever appropriate, existing utility accommodation policies should be modernized in light of these guidelines.

Definition of Terms

Some of the relevant terms used in the AASHTO guide are defined as follows (15):

clear zone:

That roadside border area, starting at the edge of the traveled way, available for use by errant vehicles.

right-of-way:

A general term denoting land, property, or interest therein, usually in a strip, acquired for or denoted to transportation purposes.

roadside:

A general term denoting the area adjoining the outer edge of the roadway. Extensive areas between the roadways of a divided highway may also be considered roadside.

roadway:

The portion of a highway, including shoulders, for vehicular use. A divided highway has two or more roadways.

traveled way:

The portion of the roadway for the movement of vehicles, exclusive of shoulders and auxiliary lanes.

Guidelines

The AASHTO guide provides a number of suggestions to follow for the location and design of utility installations within the highway right-of-way (15).

Location

(1) Poles along highways in rural areas should be located at the right-of-way line. The poles should be located outside the clear zone.

(2) Where roadside development occurs along highways in urban areas, poles should be located as close as practical to the right-of-way line. Where curbs are present, the poles should be located as far as practical behind the face of the outer curb. If it is feasible, poles should be located behind the sidewalks.

(3) When locating poles at a location other than the right-of-way line, consideration should be given to designs which use self-supporting, armless, single pole construction, with vertical alignment of wires or cables, or other methods allowed by governmental codes which provide a safe traffic environment.

(4) Guy wires and anchors should not be placed between a pole and the traveled way where it may encroach upon the clear zone.

(5) Installations of poles, guys, and other facilities should not be located in a highway median.

(6) Extensive altercation or removal of trees should be avoided in certain areas noted for their scenic quality.

Design

(1) The utility should be responsible for the design of the poles which are installed in the highway right-of-way. The highway agency should be responsible for reviewing and approving the utility's designs and proposed location of the facilities.

(2) Utility installations on, over, or under State right- of-way should as a minimum meet the requirements of the National Electrical Safety Code (13).

(3) On new installations or changes to existing utility lines, provisions should be made for planned expansion of the utility facilities. They should be planned to minimize hazards with highway traffic.

4.4 Federal Policy

The Federal Highway Administration addresses accomodation of utilities as part of Federal-Aid Highway Program Manual FHPM 6-6-3-2 (17). The subsection entitled, "Accommodation of Utilities," is included in Appendix C.

(5) Utility installations on, over, or under State right-of-way should as a minimum meet the requirements of the National Electrical Safety Code (11).

(6) On new installations or changes to existing utility lines, provisions should be made for planned expansion of the utility facilities. They should be planned to minimize hazards to the highway traffic.

4) Federal Policy

The Federal Highway Administration addressed accommodation of utilities as part of Federal-Aid Highway Program Manual (FHPM) 6-6-3-2 (12). This subsection entitled, "Accommodation of Utilities," is included in Appendix C.

5 METHODOLOGY

5.1 Introduction

The cost-effectiveness methodologies selected for use in this research study were presented in the Federal Highway Administration (FHWA) report entitled, "Selection of Cost-Effective Countermeasures For Utility Pole Accidents - User's Manual," written by Zegeer and Cynecki (18), and in the AASHTO "Roadside Design Guide" (19).

Two IBM-compatible computer programs were used in the study. The first, "UPACE," is explained in the FHWA report entitled, "Utility Pole Accident Countermeasures Evaluation Program and Input Processor-User's Manual," written by SRA Technologies, Inc. (20). The second program, "ROADSIDE," is presented in the "Roadside Design Guide" (19).

Since utility poles accidents have one the highest frequencies of severe to fatal injuries, it was determined that a cost-effectiveness methodology which dealt specifically with utility poles would be most appropriate. The "UPACE" methodology was developed to handle cost-effective countermeasures for a line of utility poles but also was applicable to luminaires or light supports. Utility poles and luminaires account for more than 17.7% of all fixed object accidents. The possibility to reduce the number of serious accidents was a potential benefit of applying the cost-effective countermeasures to both of these two dangerous roadside appurtenances. The "ROADSIDE" methodology was developed to handle cost-effective counter-measures for single utility installations such as fire hydrants, utility poles, and light poles.

The next section reviews cost-effectiveness research studies which dealt with safety improvements for fixed objects, and some previous research which served as the basis for the "UPACE" and "ROADSIDE" methodologies.

5.2 Literature Review

In 1969, Edwards et al. developed a method to improve the economic analysis of roadway illumination (21). Among the factors they considered were initial costs, accident costs resulting from vehicles colliding with light poles, and normal maintenance costs. Accident costs were subdivided into costs for structural damage to the pole and base, damage to the vehicle, and costs of injury to the occupants. Expressions were developed relating roadside illumination costs to major contributing factors for use in comparing the cost effectiveness of different lighting systems.

McFarland and Walton's 1971 study of cost-effectiveness relationships for various roadway lighting design criteria and roadway geometry (22) used cost data for initial, maintenance, operational, and accident costs. Several lighting designs were compared on a cost basis. The designs met certain levels of effectiveness on roadways with different numbers of lanes. In general, the 50 ft mounting height was preferred over the 40 ft mounting height. The research also showed that breakaway bases give large benefit-cost ratios, whatever the illumination design, if the illumination units were exposed.

In 1974, Glennon suggested a cost-effective method for prioritizing roadside safety improvement programs for freeways (23). Later that year Glennon and Wilton developed a methodology for determining the effectiveness of safety improvements for all classes of highways (24). Glennon used a probabilistic hazard index model to evaluate roadside safety improvements. The model considered roadside encroachment frequencies of vehicles (which is a function of the ADT), the percentile distribution for the lateral displacement of encroaching vehicles, the lateral placement of the roadside obstacle, the size of the obstacle, and the accident severity associated with the obstacle.

The cost-effectiveness approach served as a method to rank various safety improvement programs. The major objective for a highway department is to achieve the greatest total decrease in roadside hazards with available funds. The predicted difference between the hazard indices before and after improvements are made determines the effectiveness of the improvement. The cost-effectiveness equation is given in Equation 1.

$$\frac{\textit{Cost}}{\textit{Effectiveness}} = \frac{\textit{annualized cost of the improvement}}{\textit{hazard reduction achieved}} \quad (1)$$

$$C/E = \textit{cost to reduce one injury (fatal or nonfatal) accident}$$

In 1975, Weaver et al. used Glennon's conceptual model (23) as the basis for a structured method to evaluate safety alternatives (25). The implementation procedure served three functions: (1) conducting a detailed inventory of a highway to locate and define each roadside hazard, (2) recommending feasible safety improvement alternatives for each hazard or group of hazards, and (3) evaluating the recommended alternatives using the computer model.

The 1977 AASHTO barrier guide presented a cost-effectiveness procedure for evaluating safety alternatives (26). In 1979, Post et al. modified an earlier cost-effectiveness program developed at the Texas Transportation Institute (TTI) (25) to include a much more detailed version of the program inputs (27). The modified version used other computer models to determine impact severities.

Post and Chastain completed a cost-effectiveness study in 1982 expanding upon their earlier work (28). The cost-effectiveness methodology incorporated some other changes which included the effects of environmental conditions, vehicle size, distribution of traffic stream, et cetera.

Post et al. completed a 1979 feasibility study for implementing breakaway utility poles (29) using the cost-effectiveness methodology developed by Glennon (23). Later, McCoy et al. developed a methodology to evaluate safety improvement alternatives for utility poles (30). In 1986, Sicking and Ross completed a study which incorporated a benefit-cost analysis of roadside safety alternatives (31).

Significant modifications have been made recently to the cost-effectiveness methodology which was originally presented in the 1977 AASHTO barrier guide. They are now presented in the AASHTO "Roadside Design Guide" (19). Some of these changes include incorporation of an encroachment rate model which includes the effects of roadway curvature and grade plus opposite-direction encroachments on undivided, two-way roadways; other changes are the inclusion of a model which relates both the lateral extent of encroachment and accident severity to design speed, and a model which calculates traffic growth over the project life and incorporates this factor into the economic analysis. Another modification was the inclusion of the effect of a vehicle which has yawing motion while entering the corner zone of the hazard index model. The new cost-effectiveness selection computer program, entitled "ROADSIDE," is available for IBM or IBM-compatible personal computers.

5.3 A Conceptual Model

Glennon argued three conditions must exist in order for an impact with a roadside obstacle to occur (23): first, the vehicle must be within the section of roadway associated with the roadside obstacle; second, vehicle encroachment must occur; and third, the lateral displacement of the vehicle must be on a course of impact with the roadside obstacle.

This sequence of events suggested that a conceptual or probabilistic approach was needed to help identify hazardous roadside situations. This approach considered vehicle exposure and encroachment rate as well as the size and lateral placement of the roadside obstacle and its relative influence on accident severity. A schematic of a roadside obstacle situation of section L is shown in Figure 1. The generalized equation for determining the hazard index is given in Equation 2.

$$H = V[P(E)]\ [P(C/E)]\ [P(I/C)] \tag{2}$$

in which

H = hazard index; expected number of fatal plus nonfatal injury accidents per year;

V = vehicle exposure; number of vehicles per year passing through section L;

$P(E)$ = probability that a vehicle will encroach on the roadside within section L; encroachments per vehicle. This probability is a function of the length of exposure, L, and other environmental variables such as the geometric design of the roadway;

$P(C/E)$ = probability of a collision, given that an encroachment has occurred; accidents per encroachment. This probability is a function of the angle of encroachment, θ; the vehicle's lateral displacement (measured from the right-front corner of the vehicle), y; the lateral placement of the roadside obstacle, s; and the size of the obstacle, l and w; and

$P(I/C)$ = probability of an injury (fatal or nonfatal) accident, given a collision; fatal plus nonfatal injury accidents per total accidents.

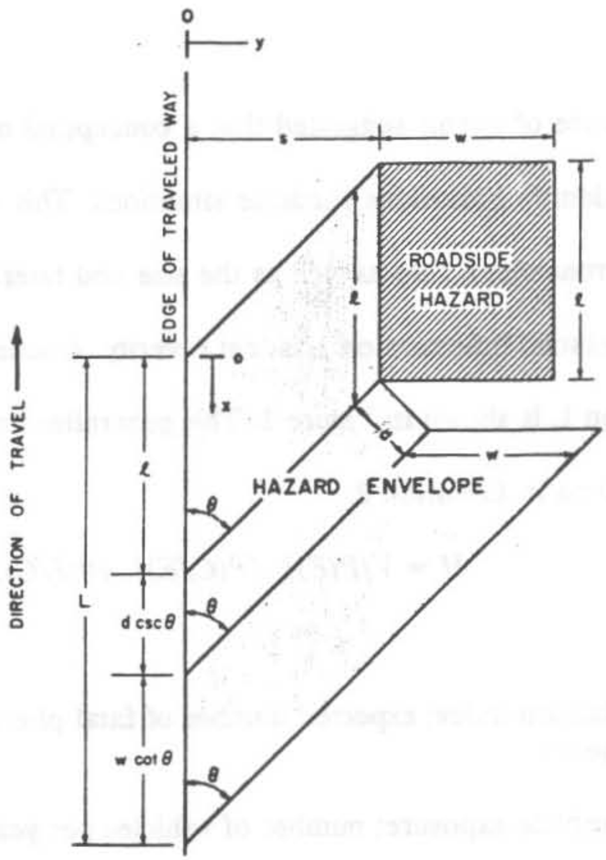


FIGURE 1. SCHEMATIC OF A ROADSIDE OBSTACLE SITUATION.

A more complex mathematical relationship was required to evaluate the hazard index of a particular roadside situation. For an encroachment angle, δ, the more detailed equation is given as Equation 3:

$$H=\frac{E_f S}{5{,}280}\left[\int_s^{\infty} f(y)\,dy+\int_l^{l+d\csc\theta}\int_{s+(x-1)\cos\theta\sin\theta}^{\infty} f(y)\,dy\,dx+\int_{l+d\csc\theta}^{l+d\csc\theta+w\cot\theta}\int_{s+d\cos\theta+(x-1-d\sec\theta)\tan\theta}^{\infty} f(y)\,dy\,dx\right] \quad (3)$$

in which

E_f = encroachment frequency, number of encroachments per mile per year;

S = severity index [previously defined as $P(I/C)$], number of fatal and nonfatal injury accidents per total accidents;

l = longitudinal length of the obstacle, feet;

w = lateral width of the obstacle, feet;

s = lateral placement of the obstacle, feet;

d = width of the vehicle, feet;

θ = angle of encroachment, degrees;

x = longitudinal distance from the farthest downstream encroachment point to the encroachment point of reference, feet; and

$f(y)$ = percentile distribution of lateral displacements of encroaching vehicles.

To simplify the mathematical hazard model, two substitutions were made. The first double integral in Equation 3 was reduced to the approximate single integral equivalent:

$$d \csc\theta \int_{s+\frac{d\cos\theta}{2}}^{\infty} f(y)\,dy \tag{4}$$

The second double integral was replaced by a single integral equivalent using a stepwise analysis of longitudinal increments. To accomplish this simplification, the encroachment length, w cot θ, was divided into a number, n, of small increments, j=1, n, and the contribution of each increment to the hazard index is calculated using the lateral displacement for the midpoint of the subsection. Thus, the second double integral in Equation 3 was replaced by

$$\frac{w\cot\theta}{n}\sum_{j=1}^{n}\int_{s+d\cos\theta+\frac{w(2j-1)}{2}}^{\infty} f(y)dy$$

Since each of the three integrals of the simplified hazard model represents a cumulative probability distribution, the equation can be written in a more understandable algebraic form. Using a 6 ft average vehicle width, the simplified hazard model for all classes of highways is given as Equation 4 (24):

$$H = \frac{E_f S}{5{,}280}\left[l\,P[y \geq s] + 6\csc\theta\,P[y \geq s + 3\cos\theta] + \frac{w\cot\theta}{n}\sum_{j=1}^{n} P\left[y \geq s + 6\cos\theta + \frac{w(2j-1)}{2n} \right] \right] \quad (4)$$

where

$P[y \geq \ldots] =$ probability of a vehicle lateral displacement greater than some value.

$n =$ number of analysis increments for the hazard associated with the obstacle width. A reasonable subdivision is one increment for each 2.5 ft of width, and

$j =$ the number of the obstacle-width increment under consideration starting consecutively with 1 at the lowest lateral placement.

This model estimates the hazard index for a particular roadside obstacle independent of other contiguous roadside obstacles. To evaluate the effectiveness of a particular roadside safety improvement, the difference in hazard index before and after improvement must be calculated.

6 "UPACE" METHODOLOGY

6.1 Introduction

In 1983, Zegeer and Parker developed a cost-effectiveness analysis procedure for the selection of alternative treatments within the highway right-of-way, with the aim of reducing utility pole accidents or reducing utility pole severity (32). The cost-effectiveness procedure was intended for use by highway designers, traffic and safety engineers, and utility company engineers and managers involved in utility pole placement and maintenance. The study involved the collection and analysis of roadside and accident data to determine the accident experience associated with various roadside and utility pole features.

A large data base was assembled which included roadway, traffic, utility pole, and utility pole accident data for each of 1,534 roadway sections covering a total of 2,519.3 miles in Michigan, North Carolina, Washington, and Colorado. The data was collected from agency files, photologs, police accident records, and site visits. Statistical analyses were performed on the data using comparative analyses and non-linear regression models to predict utility pole accidents for various combinations of utility pole and roadway features. The results were used to determine accident reduction factors and accident benefits of various combinations of pole relocation options and reductions in pole density.

Zegeer and Parker developed general guidelines for selecting countermeasures which were likely to be cost-effective under a variety of traffic and roadway conditions. An additional discussion on various countermeasures is included in Appendix D. A manual procedure and computer program were developed as a method for determining the optimal countermeasure based on the incremental benefit-to-cost ratio. The two procedures allow the user to input the specific roadway, utility pole, and accident history of a specific site.

The procedure could also be used if no utility pole accident experience was available. Zegeer and Parker developed an accident predictive model or equation which computes the expected before and after accident experience.

The computer program also can make adjustments for expected benefits due to changes in traffic volume, occupant restraint systems (airbags and seat belts), and vehicle downsizing. A brief discussion on seat belt effectiveness is included in Appendix E. One additional feature of the computer program is that it can consider the increase in other fixed object accidents which could occur after relocating utility poles or undergrounding utility lines. An example of this would be the case of encroaching vehicles impacting trees or other fixed objects which were previously behind the utility poles.

6.2 Methodology

Zegeer and Cynecki have presented two procedures, a manual method and a computer method, for determining the cost-effectiveness of safety improvement alternatives for utility poles or even luminaires.The manual procedure is a simplified version of the computerized cost-effectiveness procedure. It does not allow for projected seat belt use or vehicle downsizing in future years. The computer procedure performs a more detailed analyses for the roadside adjustment factor, computation of future traffic volumes, projected utility pole accident occurrence and severity, et cetera compared to the manual method.

6.2.1 Manual Method

The manual method consists of a series of 18 steps which are listed below. The forms which are to be completed for each specific site are included in Appendix F.

1. Complete the Site Description Form (form A).

2. Complete the Countermeasure Description Form (form B).

3. Compute Average Traffic Volume Over Project Life (ADT_A).

4. Determine the Number of Utility Pole Accidents Without Treatment (A_B).

5. Determine the Accident Reduction Factor (R_A).

6. Select the Roadside Adjustment Factor (H_R).

7. Compute the Number of Accidents Reduced (ΔA).

8. Select the Average Cost per Utility Pole Accident (C_A).

9. Compute Accident Benefits Due to Reduced Accidents (B_A).

10. Compute Accident Benefits Due to Reduced Accident Severity (B_S).

11. Compute Total Accident Benefits (B_T).

12. Determine the Change in Maintenance Costs (C_M).

13. Determine Countermeasure Installation Costs (C_I).

14. Calculate Total Project Costs (C_T).

15. Calculate the Benefit-to-Cost Ratio ($\Delta B/\Delta C$).

16. Conduct Incremental Benefit-to-Cost Ratio Analysis (B/C).

17. Evaluate Available Funding and Other Constraints.

18. Record Project Details.

An brief explanation of the 18 steps is provided in the following paragraphs. For a more detailed explanation, see the report by Zegeer and Cynecki (18).

Step #1:

The characteristics of each site should be recorded on form A, which is shown in Appendix F. The section should be relatively homogeneous in the following features: traffic volume, pole offset from roadway, and pole spacings.

While performing the site inspection, a value for the term "Roadside Coverage Factor (C_F)" is to be calculated. The term was described in NCHRP 247 (33). This quantity was developed to consider the combined effects of both point and continuous fixed objects.

The fixed object coverage factor, expressed as a percentage, corresponds to the probability of striking a fixed object given that a vehicle runs a specified distance off the road. For example, a coverage factor of 20% at 30 ft implies that a vehicle that runs at least 30 ft off the road has a probability of 0.20 of striking a fixed object within 30 ft of the road.

Step #2:

The proposed countermeasure description is recorded on form B (Appendix F).

Step #3:

The purpose of this step is to determine the average traffic volume (ADT_A) over the project life. This can be done by one of two methods: (A) by estimating a fixed growth rate per year, such as 5% per year, or (B) by estimating the overall growth factor over the project life, such as 20% over 20 years. Steps #3 through step #15 are recorded on form C, as shown in Appendix F.

Step #4:

During this step, the number of utility pole or luminaire accidents per mile per year (A_B) can be determined by two methods: (A) by nomogragh or equation, as presented in Appendix G, or (B) by actual accident experience. The nomograph was developed by Zegeer and Parker in the FHWA study on utility pole accidents (32). This is based upon the average traffic volume (ADT_A) over the project life.

The best-fit regression model developed to predict utility pole accidents is given by Equation 5.

$$Acc/Mi/Yr = \left[\frac{9.84x10^{-5}(ADT) + 3.54x10^{-2}\ (Density)}{(Offset)^{0.6}} \right] - 0.04 \qquad (5)$$

where

Acc/Mi/Yr	=	number of predicted utility pole accidents per mile per year
ADT	=	annual average daily traffic volume
Density	=	number of utility poles per mile within 30 ft of the roadway
Offset	=	average lateral offset of the utility poles (ft) from the roadway edge on the section

Step #5:

The "Accident Reduction Factor (R_A)" is calculated by using the nomograph or equation for predicting the expected utility pole accidents before and after the utility pole countermeasure has been implemented.

The value of the accident reduction factor (R_A) must be between 0.0 and 1.0. Examples of various values for R_A are presented as follows:

- Underground Utility Lines: $R_A = 1.0$ (100% of the utility pole accidents will be eliminated.)
- Relocate poles further from roadway: $0.0 < R_A < 1.0$
- Reduce the number of poles: $0.0 < R_A < 1.0$
- Install breakaway poles: $R_A = 0.0$ (The number of utility pole accidents will remain unchanged.)

Step #6:

The "Roadside Adjustment Factor (H_R)" is used to account for the increase in other run-off-road, fixed-object accidents that would likely have been utility pole accidents (i.e. run-off-road vehicles hit trees that would have been screened by the line of utility poles).

For example, when utility poles are removed, the out-of-control vehicles that would have had a reported utility pole accident may instead have: (1) no collision at all (the vehicle may recover), (2) hit some other fixed object, or (3) roll-over down the sideslope.

The roadside adjustment factor will vary between 0.0 and 1.0. When $H_R = 1.0$, there will be no increase in "other" run-off-road, fixed object accidents, since the road is level and absent of other fixed-objects. When H_R is approximately equal to 0.0, it indicates a hazardous roadside where only a small net reduction in total run-off-road accidents will occur.

The roadside adjustment factor is computed based upon predominant roadside slope, area type, pole offset, roadside coverage factor, and other factors. This factor was necessary because the hazard index model developed by Glennon (23) was found to overestimate the fatal and injury run-off-road accident rate by a factor ranging between 2 to 8, depending on the magnitude of the sideslopes and the coverage of fixed objects (33).

The roadside adjustment factor is quite complex and involves computing the probability of run-off-road accidents and utility pole accidents before and after a countermeasure has been implemented. Zegeer and Parker developed a procedure which uses combinations of 16 equations as the basis of the calculations, depending on specific roadside conditions. The formulation of the roadside adjustment factor using the 16 equations is included in Appendix H.

Step #7:

This step involves computing the number of accidents reduced per mile per year (ΔA) and is given by Equation 6.

$$\Delta A = (A_B)\ (R_A)\ (H_R)\ (L) \tag{6}$$

where

ΔA = The net number of utility pole accidents reduced per mile per year,

A_B = accident reduction factor,

R_A = roadside adjustment factor, and

L = section length in miles.

Step #8:

The average cost per utility pole accident (C_A) was calculated using the methodology presented by Zegeer and Parker (32). Table 8 shows a summary of injuries by accident severity for utility pole accidents from an analysis of 9,583 utility pole accidents. The formula for figuring (C_A) is given by Equation 7:

$$\begin{aligned} C_A \quad = \quad & (\%\ PDO\ acc.) \times (Cost/PDO\ Acc.) \\ + \quad & (\%\ Injury\ acc.) \times (Cost/injury) \times (Injuries/injury\ acc.) \\ + \quad & (\%\ Fatal\ acc.) \times (Cost/fatality) \times (Fatalities/fatal\ acc.) \\ + \quad & (\%\ Fatal\ acc.) \times (Cost/injury) \times (Injuries/fatal\ acc.) \end{aligned} \tag{7}$$

The motor vehicle accident costs were obtained from the FHWA Technical Advisory from June, 1988 (34). The costs per incident are given as follows:

Cost/fatality = \$1,500,000

Cost/injury = \$11,000

Cost/PDO = \$3,000

TABLE 8

Summary of Injuries by Accident Severity for Utility Pole Accidents

Accident Severity	Number of Accidents	Percent Accidents	Number of Persons Injured	Number of Persons Killed	Persons Injured Per Accident	Persons Killed Per Accident
PDO Accidents	5,050	52.70	0	0	0	0
Injury Accidents	4,434	46.27	5,796	0	1.31	0
Fatal Accidents	99	1.03	69	107	0.70	1.08
Total	9,583	100.00	5,865	107	0.61	0.01

From the values given in Table 8 and the costs per incident, the value for (C_A) was calculated as follows:

$$
\begin{aligned}
C_A &= (0.5270) \times (\$3{,}000) \\
&+ (0.4627) \times (\$11{,}000) \times (1.31) \\
&+ (0.0103) \times (\$1{,}500{,}000) \times (1.08) \\
&+ (0.0103) \times (11{,}000) \times (0.7) \\
&= \$1{,}581.00 + \$6{,}667.51 + \$16{,}686.00 + \$79.31 \\
&= \$25{,}013.82 \text{ per utility pole accident.}
\end{aligned}
$$

Step #9:

This step calculates the accident benefits due to a reduction in accident occurrence (B_A). This step is performed for the following types of countermeasures: undergrounding, pole relocation, multiple pole use, or increasing pole spacing. For the breakaway pole countermeasure, skip to step #10B.

Equation 8 shows how the value of (B_A) is determined:

$$B_A = (\Delta A) \times (C_A) \quad (8)$$

where

B_A = accident benefits per year based upon a net reduction in accident occurrence,

ΔA = net reduction in accidents, and

C_A = average cost per utility pole accident.

Step #10:

This step calculates the accident benefits due to a reduction in accident severity (B_S). For the countermeasures of undergrounding, increasing lateral pole offset, multiple pole use, or increasing pole spacing go to step #10A. For the case of installing breakaway poles, go to step #10B.

Step #10A:

When H_R is less than 1.0, a portion of the utility pole accidents eliminated will be converted to other run-off-road accidents after the countermeasure installation. However, Zegeer and Parker found that, since the severity of utility pole accidents is generally greater than the severity of other run-off-road accidents, (except for roll-over accidents), benefits due to a reduction in accident severity could be expected (32). If $H_R = 1.0$, there would be no increase in run-off-road accidents, and B_S would be equal to 0.0.

Depending on the area type (rural or urban), the posted speed limit, and the predominate types of other fixed objects, Zegeer and Cynecki stated there was approximately a 40% expected reduction in accident severity for non-utility pole run-off-road accidents (18). This occurs in urban areas where posted speeds are less than 45 mph. From the accident analysis performed by both Jones and Baum (9) and also by Zegeer and Parker (32), the accident severities for utility pole and run-off-road accidents were found to be 47.3% and approximately 30%, respectively.

TABLE 9

Change in Accident Costs (ΔC_A) due to a Reduction in Accident Severity

Percent Reduction In Injury Plus Fatal Accidents	Percent Accidents By Severity			Accident Cost (C_A)*	Reduction In Accident Cost (ΔC_A)
	PDO	I	F		
0	52.70	46.27	1.03	$ 25,014	$ 0
5	55.06	43.96	0.98	23,938	1,076
10	57.43	41.64	0.93	22,861	2,153
15	59.79	39.33	0.88	21,785	3,229
20	62.16	37.02	0.82	20,547	4,467
25	64.53	34.70	0.77	19,469	5,545
30	66.89	32.39	0.72	18,394	6,620
35	69.25	30.08	0.67	17,318	7,696
40	71.62	27.76	0.62	16,241	8,773
45	73.98	25.45	0.57	15,165	9,849
50	76.34	23.14	0.52	14,089	10,925

* Based on the 1988 FHWA accident costs.

From Table 9, the difference in cost between utility pole accidents and other run-off-road accidents (ΔC_A) was determined to be approximately $8,773 in urban areas with speeds less than 45 mph. This was based upon the 1988 FHWA costs. In rural areas, where speeds are 45 mph or greater, Zegeer and Parker (32) found little evidence to suggest a difference in accident severity between utility pole and other fixed-object accidents.

Example: 40% reduction in $I+F$

$$I: \quad (0.4627) - (0.40 \times 0.4627) = 0.2776 \text{ or } 27.76\%$$
$$F: \quad (0.0103) - (0.40 \times 0.0103) = 0.0062 \text{ or } 0.62\%$$
$$PDO: \quad 100\% - 28.38\% = 71.62\%$$

$$\begin{aligned} C_A &= (0.7162)(\$3,000) + (0.2776)(\$11,000)(1.31) \\ &+ (0.0062)(\$1,500,000)(1.08) + (0.0062)(\$11,000)(0.7) \\ &= \$2,148.60 + \$4,000.22 + \$10,044.00 + \$47.74 \\ &= \$16,240.56 \\ \Delta C_A &= \$25,014 - \$16,241 = \underline{\$8,773} \end{aligned}$$

The equation for determining the benefit due to a reduction in severity (B_S) is given in Equation 9.

$$B_S = (1-H_R)\times(A_B)\times(R_A)\times(\Delta C_A)\times(L) \tag{9}$$

where

B_S = accident benefits due to a reduction in accident severity for utility pole accidents converted to other run-off-road accidents

H_R = roadside adjustment factor

A_B = number of utility pole accidents per mile per year

R_A = utility pole accident reduction factor

ΔC_A = difference in cost between utility pole accidents and other run-off-road accidents, and

L = section length in miles.

Step #10B:

This step is only applicable for the use of breakaway poles. When breakaway poles are used, there would not be any change in accident frequency (B_A=0.0), but there would be an expected reduction in the accident severity. The equation for calculating the benefit due to a reduction in accident severity is given as Equation 10.

$$B_S = (A_B)\times(\Delta C_A)\times(L) \tag{10}$$

where

B_S = accident benefits due to a reduction in accident severity from the use of breakaway pole,

ΔC_A = difference in accident cost from the use of breakaway devices, and

L = section length in miles.

Table 10 provides various values for (ΔC_A) which correspond to different levels of percent reduction in injury and fatal accidents when using breakaway devices.

TABLE 10
Values of Cost Recution (ΔC_A) due to Reductions in Accident Severity from Breakaway Devices

Percent Reduction In Injury Plus Fatal Accidents	Percent Injury Plus Fatal Accidents Using Breakaway Devices	Average Cost Per Utility Pole Accident (C_A)*	Differences In Average Accident Cost (ΔC_A)
0	47.3	$ 25,014	$ 0
5	44.94	23,938	1,076
10	42.57	22,861	2,153
15	40.21	21,785	3,229
20	37.84	20,547	4,467
25	35.47	19,469	5,545
30	33.11	18,394	6,620
35	30.75	17,318	7,696
40	28.38	16,241	8,773
45	26.02	15,165	9,849
50	23.66	14,089	10,925
55	21.28	12,849	12,165
60	18.92	11,773	13,241
65	16.55	10,696	14,318
70	14.11	9,620	15,394
75	11.83	8,544	16,470
80	9.46	7,467	17,547
85	7.09	6,229	18,785
90	4.73	5,153	19,861
95	2.36	4,076	20,938
100	0.00	3,000	22,014

*Based on the 1988 FHWA accident costs.

Step #11:

The total benefits (B_T) are now calculated, which are due to the reduced number of accidents and reduced accident severity. Equation 11 gives the total accident benefit.

$$B_T = B_A + B_S \tag{11}$$

where

$B_T =$ total accident benefits per year

B_A = accident benefits due to reduced accident occurrences per year, and

B_S = accident benefits due to reduced accident severity per year.

Step #12:

The change in maintenance costs (C_M) are now calculated on an annual basis over the entire section length, as given by Equation 12.

$$C_M = (C_{MB} \times L) - (C_{MA} \times L) \quad (12)$$

where

C_M = change in maintenance costs per year due to the countermeasure,

C_{MB} = maintenance costs per mile per year before countermeasure installation,

C_{MA} = maintenance costs per mile per year after countermeasure installation, and

L = section length in miles.

If the maintenance costs are unknown, a value of $0 should be used for the change in maintenance costs.

Step #13:

The countermeasure installation costs (C_I) are now determined. This includes the cost of removing an old line of poles, purchasing right-of-way (if applicable), and the countermeasure costs of either undergrounding utility lines, increasing lateral pole offset, increasing pole spacing, or eliminating one line of poles where two existed.

If the countermeasure costs are unknown, Zegeer and Parker developed various tables for average countermeasure installation costs (32). Their cost information was obtained from a survey of 12 telephone companies in 21 states and 31 electric companies in 20 states across the United States in 1981. If available, current installation cost estimates should be used rather than the old cost values given by Zegeer and Parker. It is noted that the cost tables developed by Zegeer and Parker do not include the costs of additional right-of-way acquisition.

The average cost information for breakaway utility poles is limited due to only a small number of installations currently in the field. For the available cost information, see the literature review on breakaway utility poles in Appendix I.

The installation costs should be given in dollars per year. A conversion must take place, because the costs are typically given as either cost per mile (C_L), cost per pole (C_P), or lump a sum cost (C_S). Equations 13, 14, and 15 are used to convert the following costs to an equivalent uniform annual cost.

$$C_I = (C_L) \times (CRF^i n) \times (L) \tag{13}$$

$$C_I = (C_p) \times (P_L) \times (CRF^i n) \times (L) \tag{14}$$

$$C_I = (C_S) \times (CRF^i n) \tag{15}$$

where

C_I = initial construction costs amortized over the entire project period (n years),

C_L = initial construction costs per mile,

$CRF^i n$ = capital recovery factor at an interest rate i over the project life of n years,

L = section length in miles,

C_P = initial construction costs per utility pole,

P_L = number of utility pole per mile, and

C_S = total initial construction cost.

The capital recovery factor is used to determine the amount of each future annuity payment required to accumulate a given present value when the interest rate and number of payments are known. It is also known as *(A/P,i%,n)* and given as Equation 16.

$$CRF^{i}n = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{16}$$

Step #14:

The total costs (C_T) are now calculated, which are due to the change in annual maintenance cost and the equivalent uniform annual construction cost. Equation 17 gives the total costs.

$$C_T = C_M + C_I \tag{17}$$

where

C_T = total project cost amortized over the project life,

C_M = change in maintenance costs per year due to the countermeasure, and

C_I = initial construction costs amortized over the entire project period.

Step #15:

The benefit-to-cost ratio (B/C) for the countermeasure is the total benefits divided by the total costs, as shown in Equation 18.

$$\frac{B}{C} = \frac{B_T}{C_T} \tag{18}$$

where

B/C = benefit-to-cost ratio for the countermeasure,

B_T = total accident benefits, and

C_T = total countermeasure costs.

Step #16:

Once various countermeasures have been evaluated on the benefit-to-cost ratio basis, a decision must be made whether or not implementation of a specific project is feasible. If only one countermeasure is performed, usually a benefit-to-cost ratio greater than or equal to 1.0 is acceptable. If more than one countermeasure is evaluated, a type of analysis which will compare the countermeasures must be performed.

A method for performing this comparison is the incremental benefit-to-cost ratio procedure ($\Delta B/\Delta C$), as shown on form D in Appendix F. The incremental benefit-to-cost ratio method is used to select countermeasures based on whether extra increments of expenditures (i.e., underground lines as opposed to pole relocation) are justified for a particular location. It also could be used for considering improvements at two or more locations when evaluating what projects should be funded. The method assumes that the relative merit of a project is measured by its increased benefits (compared to the next lower cost alternative) divided by its increased costs (compared to the next lower cost alternative).

To perform the incremental benefit-to-cost ratio, first eliminate the alternatives which have B/C ratios less than or equal to 1.0 or some other minimum value. Next, rank the remaining projects in the order from lowest cost to highest cost (C_T), as shown in Table 11.

TABLE 11

Incremental Benefit-to-Cost Ratio ($\Delta B/\Delta C$) Procedure

Alternative Ranking	Total Benefits (B_T)	Total Costs (C_T)	Incremental Change in Benefits (ΔB)	Incremental Change in Costs (ΔC)	Comparison	Incremental Benefit-to-Cost Ratio ($\Delta B/\Delta C$)
1[a]	B_1	C_1	- -	–	- -	- -
2	B_2	C_2	$B_2 - B_1$	$C_2 - C_1$	2 - 1	$(B_2 - B_1) / (C_2 - C_1)$
3	B_3	C_3	$B_3 - B_2$	$C_3 - C_2$	3 - 2	$(B_3 - B_2) / (C_3 - C_2)$
4	B_4	C_4	$B_4 - B_3$	$C_4 - C_3$	4 - 3	$(B_4 - B_3) / (C_4 - C_3)$
5[b]	B_5	C_5	$B_5 - B_4$	$C_5 - C_4$	5 - 4	$(B_5 - B_4) / (C_5 - C_4)$

[a] Lowest Cost
[b] Highest Cost

Starting with alternative #2 (second lowest cost - C_T), compare the incremental cost ($C_2 - C_1$) with the incremental benefits ($B_2 - B_1$). If the incremental benefits ($B_2 - B_1$) are greater than the incremental costs ($C_2 - C_1$) or $\Delta B/\Delta C$ is greater than 1.0, then alternative #2 is justified, and alternative #1 should be eliminated from consideration. If the incremental benefits ($B_2 - B_1$) are less than the incremental costs ($C_2 - C_1$) or $\Delta B/\Delta C$ is less than 1.0, then alternative #1 is justified, and alternative #2 should be eliminated from consideration. The justified alternative, from either #1 or #2, should be compared to alternative #3 by incremental benefit to incremental cost. The procedure is complete when only one alternative remains.

Step #17:

Once an optimal countermeasure has been selected by an incremental benefit-to-cost ratio analysis, the agency must determine whether available funding can be provided to implement the project. If sufficient funds are not available or other contraints prohibit the implementation of the project, then, the next highest rated countermeasure must be selected and evaluated for available funding.

Step #18:

The project details for the selected countermeasure should be documented for future reference.

6.2.2 Computer Method

The cost-effectiveness methodology has also been adapted for the use of computers. The original version of "UPACE" or Utility Pole Accident Countermeasure Evaluation computer program was developed on a Amdahl 470/V8 computer system, and a version was developed for use on a microcomputer operating under the UCSD P-System. Since most highway engineers have access to an IBM-PC or IBM-compatible microcomputer, a version of "UPACE" was converted to be run under a DOS operating system.

Since "UPACE" requires a great deal of data input, a user-friendly input processor, known as "UPACEI", was developed to assist the user in creating or modifying data sets.

The data required by "UPACE" may be grouped into six categories which correspond to the first six selections of the data file creation or modification menus in "UPACEI". The six categories of data are listed as follows:

1. roadway section data
2. utility pole data
3. traffic data
4. accident/severity data
5. economic analysis data
6. countermeasure data

The "UPACE" computer program is set up to have the user enter or modify the input data in groups of similar items arranged on a series of screens. Once "UPACEI" is exited, the data is stored and can be run with the "UPACE" program. The program performs six basic steps which are detailed in the flowchart in Figure 2.

1. Read and check input data.
2. Estimate future traffic rates.
3. Predict future accidents and their severity, if no improvements are made.
4. Analyze each alternative countermeasure, determining the benefits and costs of the improvements.
5. Compare the alternative countermeasures analyzed.
6. Generate output reports.

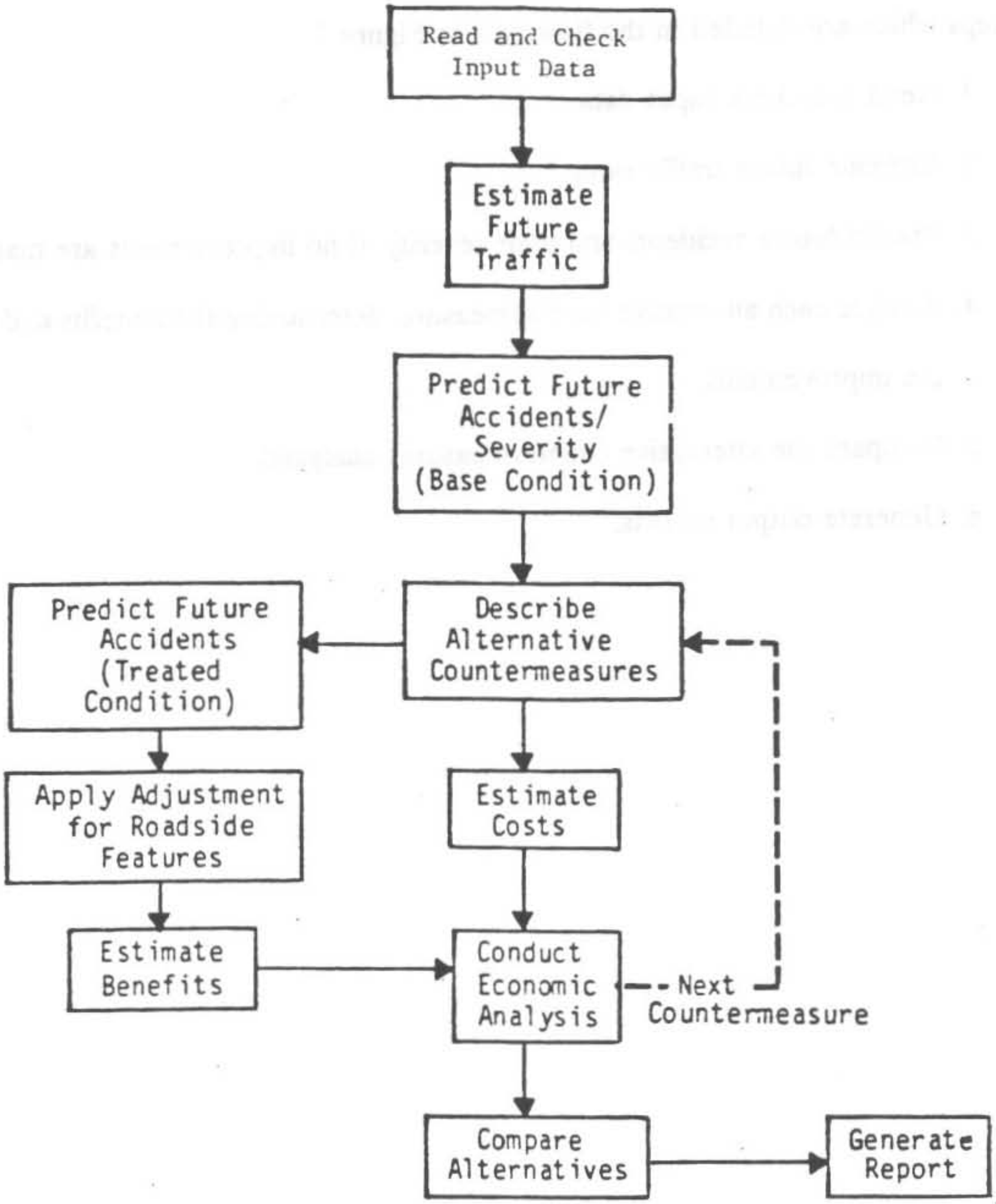


FIGURE 2. FLOWCHART OF THE UPACE COMPUTER PROGRAM.

7 "UPACE"FIELD SITE DESCRIPTIONS

Cost-effectiveness analyses were performed on seven field sites in Omaha, Lincoln, and Wayne, Nebraska. The sites were selected by the Nebraska Department of Roads and involved either utility or light poles. The use of these "real-world" sites validated the computer study and also gave researchers a real feel for the problems confronting designers. Although construction drawings were available for the field sites, it was felt that the best way to understand the required computer inputs was to visit each location. The seven field sites are discussed below.

7.1 Site #1: East "O" St.

Site #1 was an area of approximately 13,200 ft (2.5 mi.) along "O" St. from 27th St. to 63rd St., in Lincoln, Nebraska. The street is classified as a municipal state highway in the Nebraska classification system; the roadway is known as Highway US 34, which is a two-way, four-lane, curbed section. The posted speed limit was 40 mph.

The project at this site involved removing and relocating the existing luminaires or light poles from an average lateral offset of 2.25 ft to the current standard of 6 ft. The actual measured average lateral offset of the luminaires was found to be approximately 7.57 ft. The number of poles was reduced from 167 poles to 103 poles. After completion of the project, field visits determined that approximately 70 poles were now in clear areas which could be impacted; other light poles had been relocated behind other fixed objects such as walls, trees, fences, etc., as shown in Figure 3. The luminaires or light poles were located on both sides of the roadway.

Photographs of the roadway section after the implementation of the project are shown in Figures 3, 4, and 5. Evidently, the light poles had an average lateral offset greater than 6 ft because they were placed at the outside edge of the sidewalk.

The actual costs of the project were as follows:

Construction Costs:	<u>$470,682.14</u>
Total:	$625,882.62

The actual accident experience before the implementation of the project for the existing light poles was 20 accidents over a period of 2.38 years or 8.40 accidents per year. The accident severity was 11 PDO's (55%), 9 injury accidents (45%), and 0 fatal accidents (0%) over the period from January 1, 1984 to May 16, 1986.

The actual accident experience after the implementation of the project for the relocated light poles was 4 accidents over a period of 1.64 years or 2.44 accidents per year. The accident severity was 1 PDO (25%), 3 injury accidents (75%), and 0 fatal accidents (0%) over the period May 13, 1987 to December 31, 1988.

The ADT before the project began was found to be approximately 30,035 (1982). The current average ADT over the entire section length was approximately 35,622; this is an average annual traffic growth of approximately 2.5%. The roadside coverage factor of the fixed objects was found to be approximately 60.5% with an average lateral offset of 10.12 ft (Appendix J).

In performing the field work for the fixed object analysis, many situations were encountered which were not addressed in the guidelines for determining the roadside coverage factor. As evident in the lower photograph in Figure 5, vehicles may be located adjacent to the roadway in a shopping mall parking lot. Since these vehicles were not

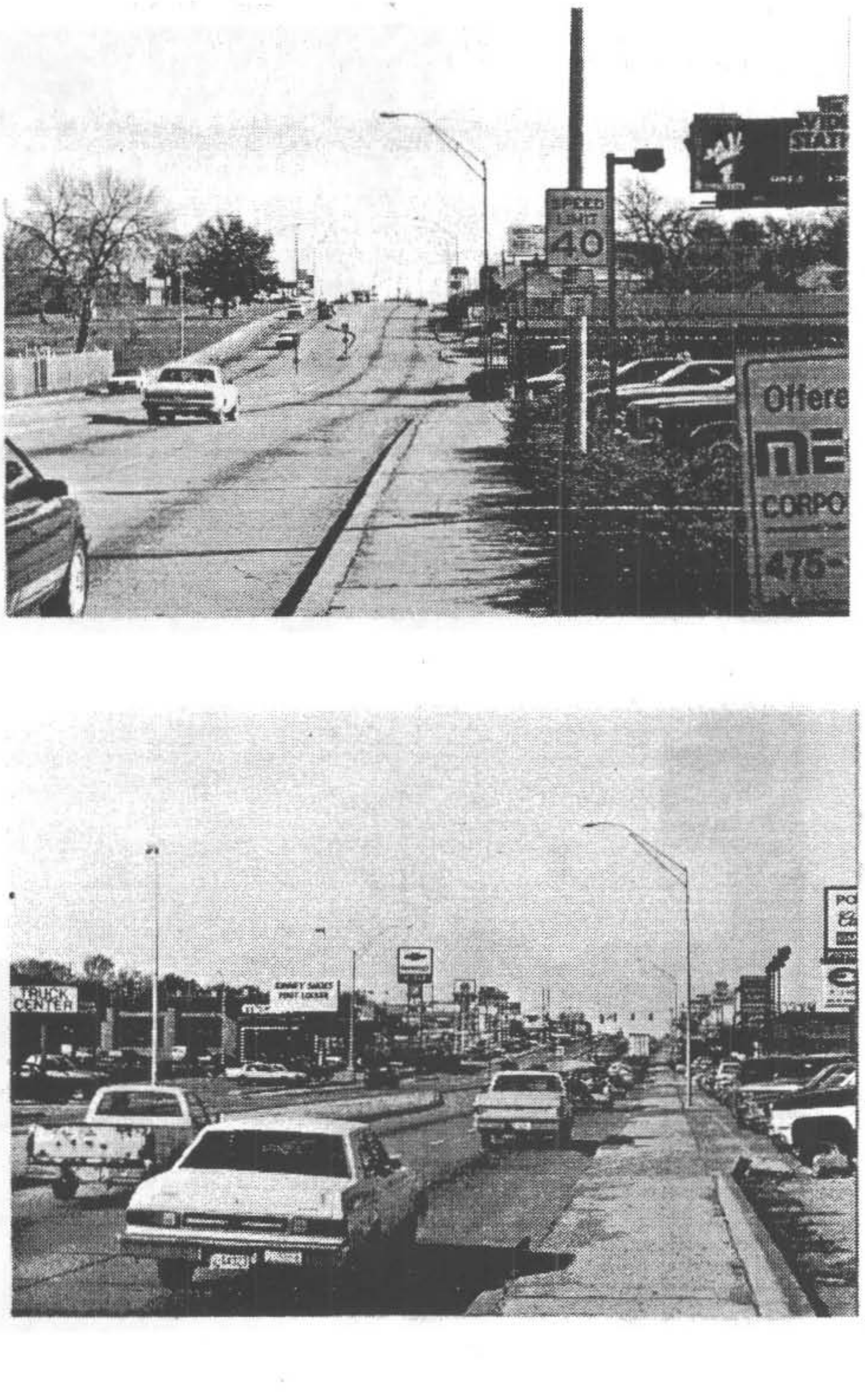


FIGURE 3. PHOTOGRAPHS OF THE "O" ST. SAFETY IMPROVEMENT PROJECT.

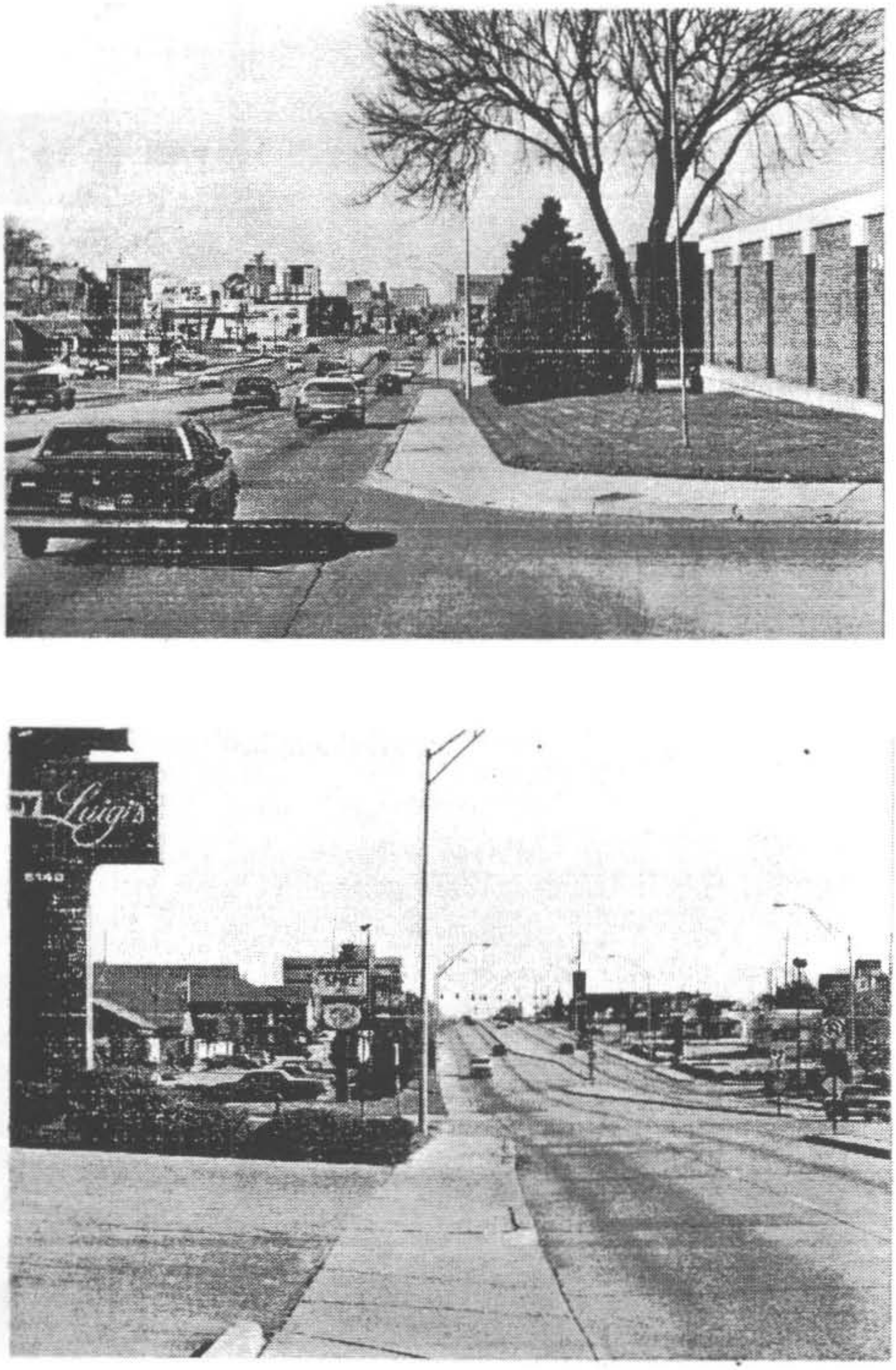
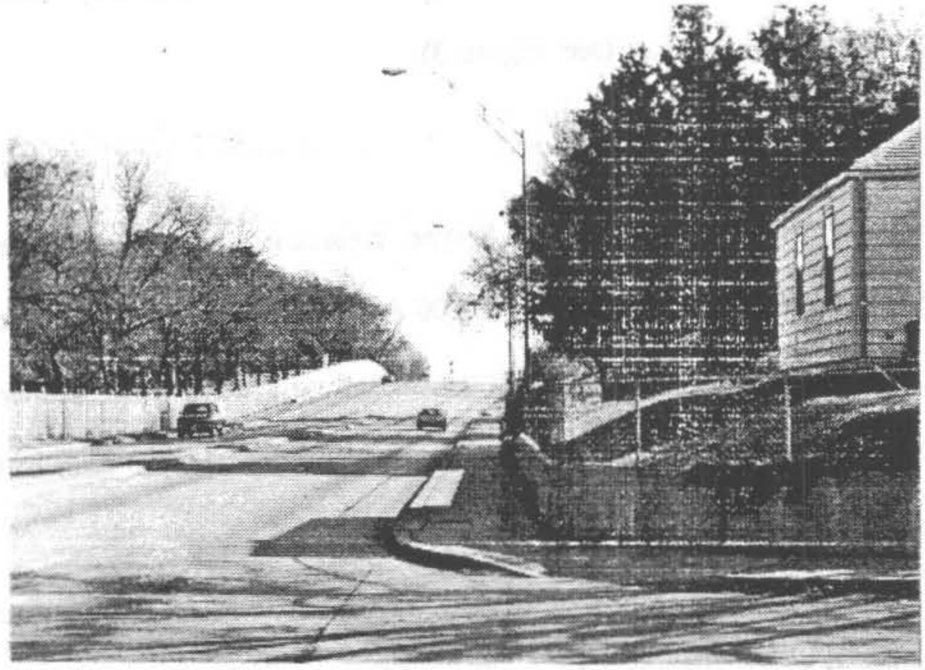


FIGURE 4. PHOTOGRAPHS OF THE "O" ST. SAFETY IMPROVEMENT PROJECT.



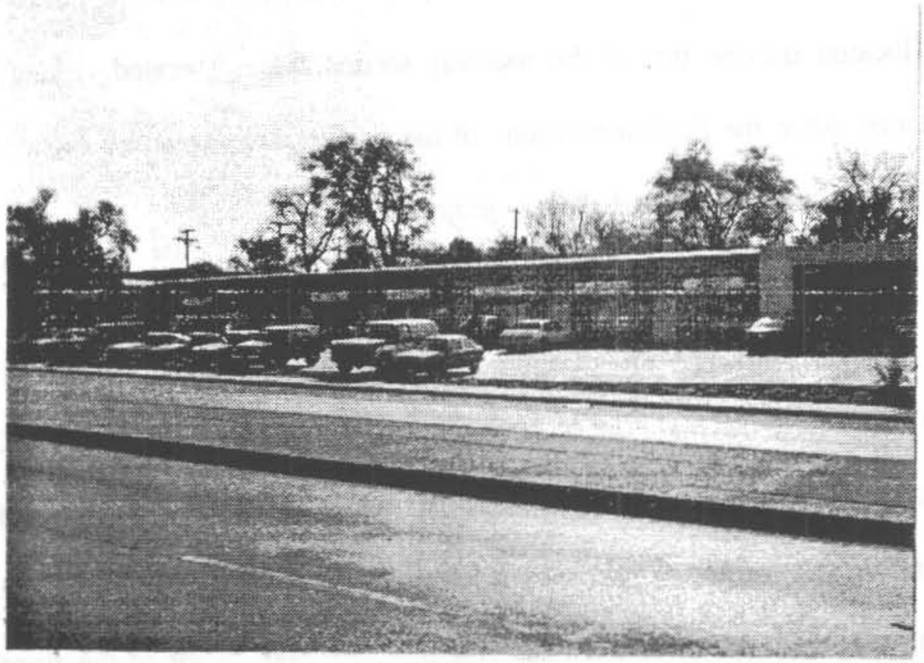


FIGURE 5. PHOTOGRAPHS OF THE "O" ST. SAFETY IMPROVEMENT PROJECT.

present 24 hours a day, an estimate of 50% of the obstructed length was used to account for the partial obstruction time. Auto dealers' lots were treated as if they were a continuous wall along the roadway section (see Figure 3).

7.2 Site #2: West 7th St.

Site #2 was located in the city of Wayne, Nebraska, along 7th St. from Sherman St. to Main St., a length of approximately 2,000 ft (0.38 mi.). The street is classified as a municipal state highway in the Nebraska classification system; the roadway is known as Highway N 35, which is a two-way, two-lane, curbed section. At the time of the study, the posted speed limit was 30 mph.

The project implemented along this roadway section relocated the existing luminaires and utility poles from an average lateral offset of 2.44 ft to the current standard of 6 ft. The actual measured average lateral offset of the poles was found to be approximately 9.67 ft. Nine poles located on one side of the roadway section were relocated. Photographs of the roadway section after the implementation of the project are shown in Figure 6.

The actual costs of the relocation project were as follows:

Construction Costs:	$5,299.12
Total:	$5,299.12

The actual accident experience revealed that only a small number of PDO accidents occurred along the roadway section between the period of June 1, 1979 to May 31, 1984. The ADT before the project began was approximately 5,480 (1982); the average annual traffic growth was reported to be 2%. The roadside coverage factor of the fixed objects was found to be approximately 59.3% with an average lateral offset of 9.39 ft (Appendix J).

FIGURE 6. PHOTOGRAPHS OF THE WEST 7TH ST. SAFETY IMPROVEMENT PROJECT.

7.3 Site #3: East 7th St.

Site #3 was located in Wayne, Nebraska along 7th St. from Nebraska St. to Walnut St., a length of approximately 1,400 ft (0.28 mi.). The street is classified as a municipal state highway in the Nebraska classification system. The roadway is known as Highway N 35, which is a two-way, two-lane, curbed section. The posted speed limit at the time of the study was 30 mph.

The project implemented along this roadway section relocated the existing the existing luminaires and utility poles from an average lateral offset of 3.00 ft to the current standard of 6 ft. The actual measured average lateral offset of the poles was found to be approximately 10.25 ft. A total of 9 poles, located on both sides of the roadway, were relocated. Photographs of the roadway section after the implementation of the project are shown in Figure 7. The actual costs of the relocation project were as follows:

Construction Costs:	$3,372.10
Total:	$3,372.10

The actual accident experience revealed that only a small number of PDO accidents occurred along the roadway section between the period of June 1, 1979 to May 31, 1984. The ADT before the project began was found to be approximately 5,480 which was in 1982. The average annual traffic growth was reported to be 2%. The roadside coverage factor of the fixed objects was found to be approximately 58.0% with an average lateral offset of 8.91 ft (Appendix J).

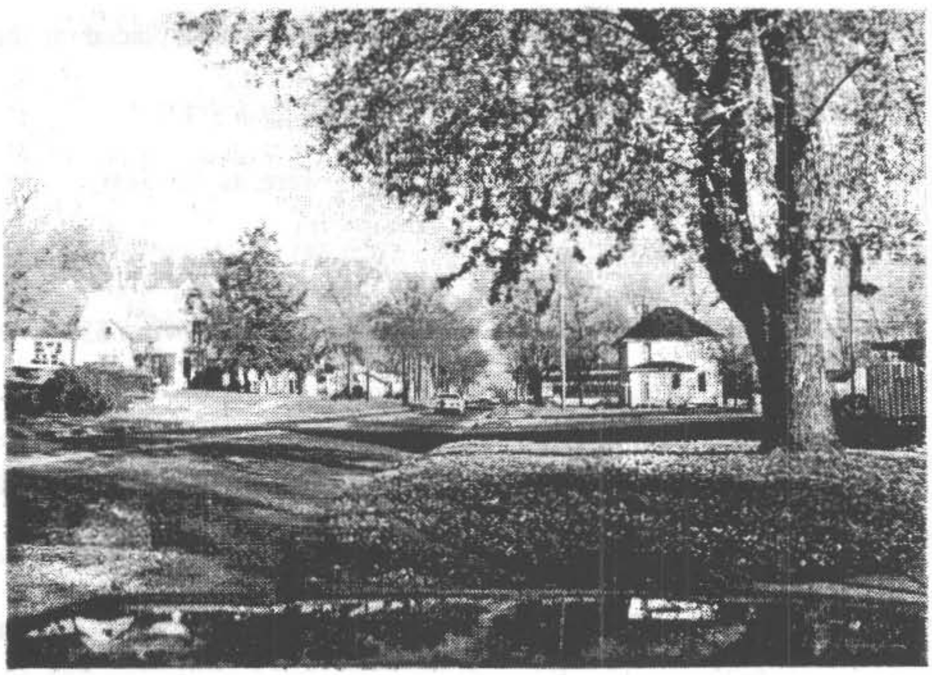


FIGURE 7. PHOTOGRAPHS OF THE EAST 7TH ST. SAFETY IMPROVEMENT PROJECT.

7.4 Site #4: Florence Blvd.

Site #4 was located in the city of Omaha, Nebraska, along Florence Blvd. from Cuming St. to Lake St., a length of approximately 4,900 ft (0.93 mi.). The street is classified as a municipal street in the Nebraska classification system; the roadway is a one-way, three-lane, curbed section, which also has one shoulder lane. The posted speed limit at the time of the study was 35 mph.

The project implemented along this roadway section removed and relocated the existing luminaires or light poles from an average of 3.39 ft to the current standard of 6 ft. The actual measured average lateral offset was found to be approximately 8.25 ft. The number of poles was increased from 49 poles to 59 poles. The luminaires or light poles were located on both sides of the roadway.

Photographs of the roadway section after the implementation of the project are shown in Figures 8 and 9. It was evident that the reason the light poles had an average lateral offset greater than 6 ft was due to the light poles being placed at the outside edge of the sidewalk.

The estimated relocation costs of the project were as follows:

Installation Costs:	$47,200	(59 x $800)
Removal Costs:	<u>$15,925</u>	(49 x $325)
Total:	$63,125	

Data on accident experience before the implementation of the project was limited; accident data are kept for only the last five year period on the computer system in the City of Omaha. Thus, only a small sample period was available for analysis. The analysis revealed no street light pole accidents during the period January 1, 1984 to April 8, 1985.

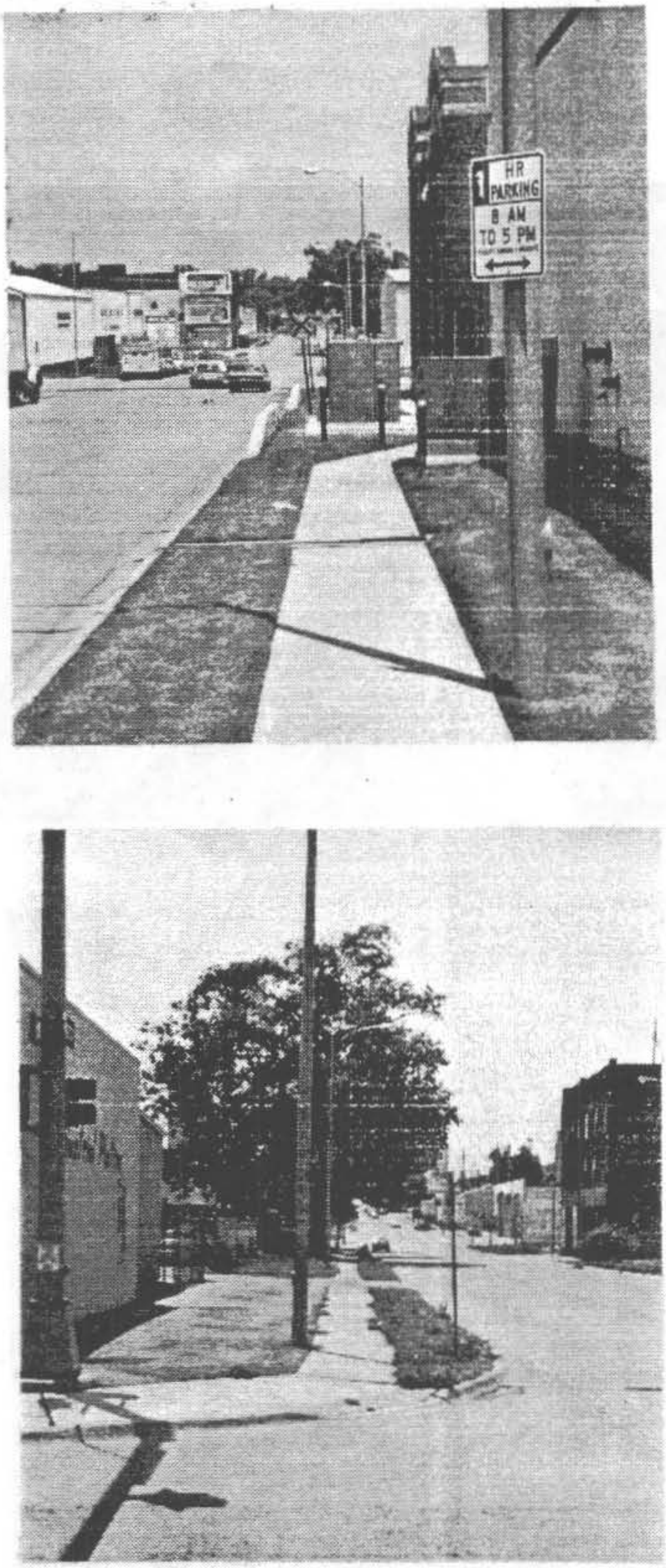


FIGURE 8. PHOTOGRAPHS OF THE FLORENCE BLVD. SAFETY IMPROVEMENT PROJECT.

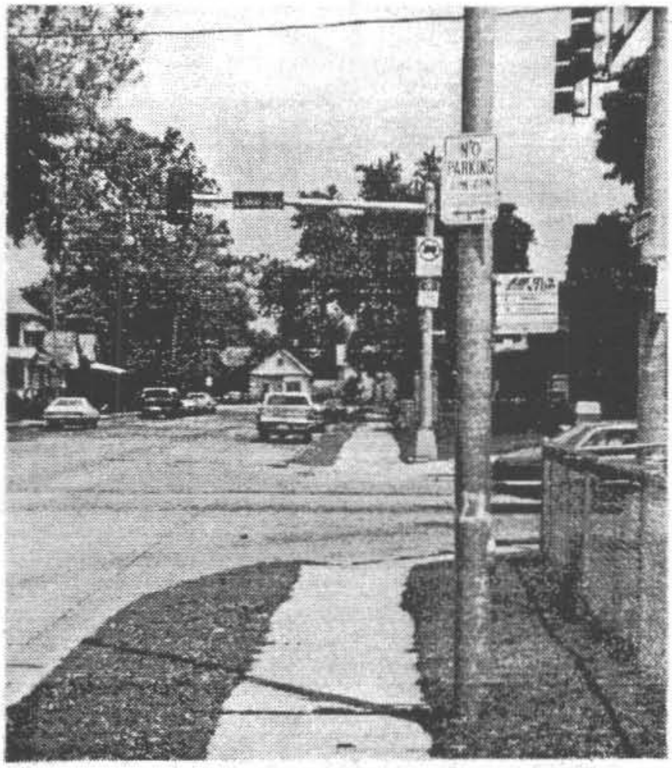


FIGURE 9. PHOTOGRAPHS OF THE FLORENCE BLVD. SAFETY IMPROVEMENT PROJECT.

The actual accident experience after the implementation of the project for the relocated light poles was one accident over a period of 3.64 years or 0.27 accident per year. This occurred from June 6, 1986 to January 24, 1990.

The ADT before the project began was found to be approximately 4,800 (1984). The 1988 average ADT over the entire section length was approximately 2,900 due to the opening of another roadway. The expected average annual traffic growth after 1988 was 2%.

The roadside coverage factor of the fixed objects for the "before" site conditions was found to be approximately 55.6% with an average lateral offset of 11.53 ft (Appendix J). The roadside coverage factor of the fixed objects for the "after" site conditions was found to be approximately 57.3% with an average lateral offset of 12.22 ft (Appendix J).

7.5 Site #5: 36th St.

Site #5 was located in the city of Omaha, Nebraska along 36th St. from Edward Babe Gomez St. to "R" St., a length of approximately 2,200 ft (0.42 mi.). The street is classified as a municipal street in the Nebraska classification system. The roadway is a two-way, two-lane, curbed section, with a center turn-lane. The posted speed limit was 30 mph.

The project which was implemented along this roadway section involved the removal and relocation of the existing luminaires or light supports, and removal of the utility poles from an average of 3.25 ft to the current standard of 6 ft. The utility lines were buried. The actual measured average lateral offset was found to be approximately 9.31 ft. The number of poles was reduced from 20 to 13 poles. Before the project, the luminaires or light poles were located on both sides of the roadway; the luminaires are now located on one side of the roadway.

Photographs of the roadway section after the implementation of the project are shown in Figures 10 and 11. From the photographs it can be seen that the reason the light poles have an average lateral offset greater than 6 ft is due to their being placed at the outside edge of the sidewalk.

The estimated relocation costs of the project were as follows:

Construction Costs:	$231,000 (275,000 per half mile)
Total:	$231,000

The actual accident experience after the implementation of the project for the relocated light poles was 0 accidents over a period of 4.23 years or 0 accidents per year. This occurred from November 1, 1985 to January 24, 1990.

The ADT before the project began was approximately 7,200 in 1985. The 1988 average ADT over the entire section length was found to be approximately 10,900. This expected average annual traffic growth after 1988 was 2%.

The roadside coverage factor of the fixed objects for the "before" site conditions was found to be approximately 63.0% with an average lateral offset of 11.56 ft (Appendix J). The roadside coverage factor of the fixed objects for the "after" site conditions was found to be approximately 56.0% with an average lateral offset of 15.04 ft (Appendix J).

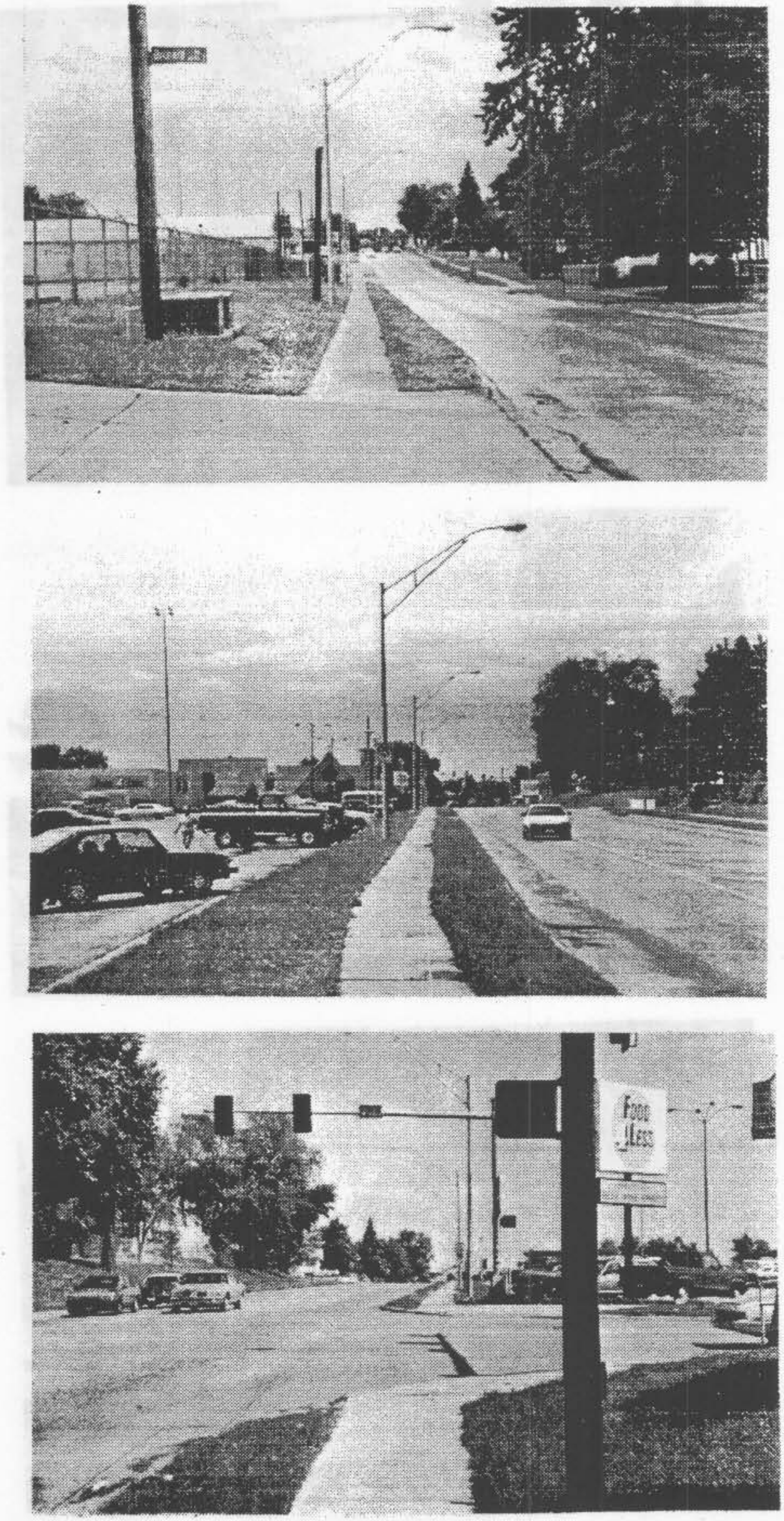


FIGURE 10. PHOTOGRAPHS OF THE 36th ST. SAFETY IMPROVEMENT PROJECT.

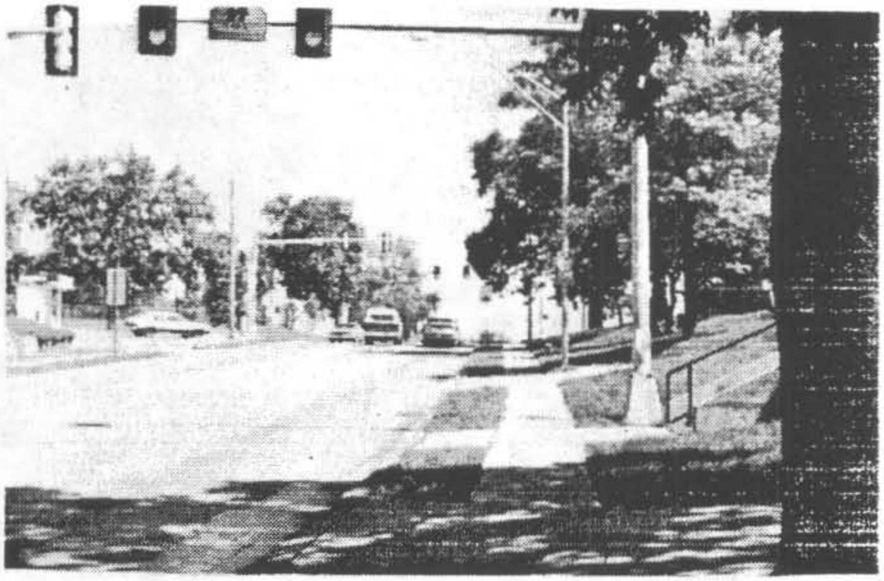


FIGURE 11. PHOTOGRAPHS OF THE 36th ST. SAFETY IMPROVEMENT PROJECT.

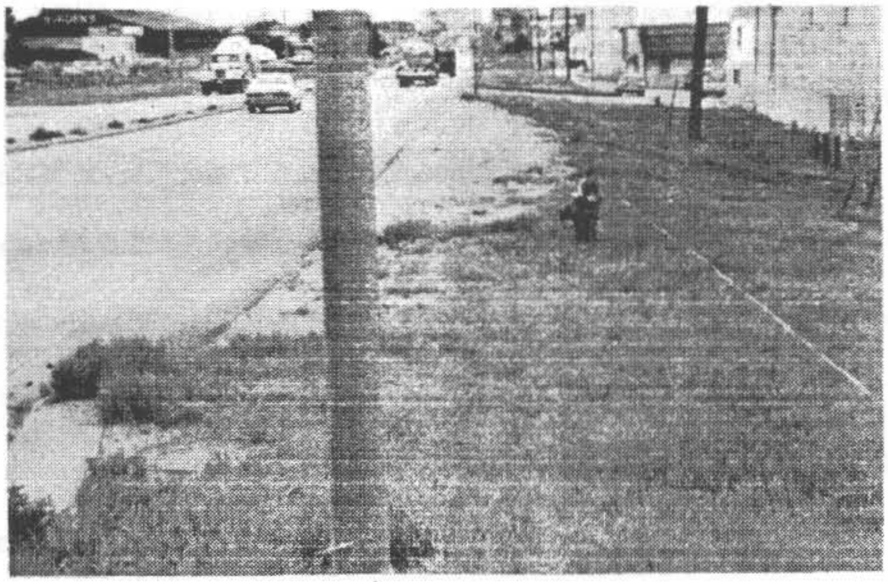
7.6 Site #6: West "O" St. (to 211+00)

Site #6 was located in the city of Lincoln, Nebraska, along West "O" St. from Capitol Beach Blvd. to Station 211+00, a distance of approximately 3,400 ft (0.64 mi.). The street is also classified as a municipal state highway in the Nebraska classification system. The roadway is known as Highway US 6, which is currently a two-way, four-lane, non-curbed section. The posted speed limit was 40 mph.

The project which is to be implemented at this site will remove and relocate the existing luminaires or light supports from an average lateral offset of 8.00 ft to some future offset which is greater than or equal to the current standard of 6 ft for curbed sections. The current field conditions revealed that the luminaire's average lateral offset from the edge of the traveled way was composed of 3 ft to 3.5 ft of shoulder and 4.5 ft to 5 ft of additional offset beyond the shoulder. The actual measured average lateral offset of the luminaires was calculated from the proposed project plans as 8.82 ft. The number of poles will be reduced from 34 poles to 22 poles. The luminaires or light poles are currently located on both sides of the roadway.

Photographs of the roadway section before the implementation of the project are shown in Figures 12 and 13. The projected costs of improved and/or new roadway lighting are as follows:

Installation Costs:	\$16,000 (20 x \$800)
Installation Costs:	\$ 3,200 (2 x \$1,600 est.) arm pole
Removal Costs:	<u>\$11,050</u>
Total:	\$30,250



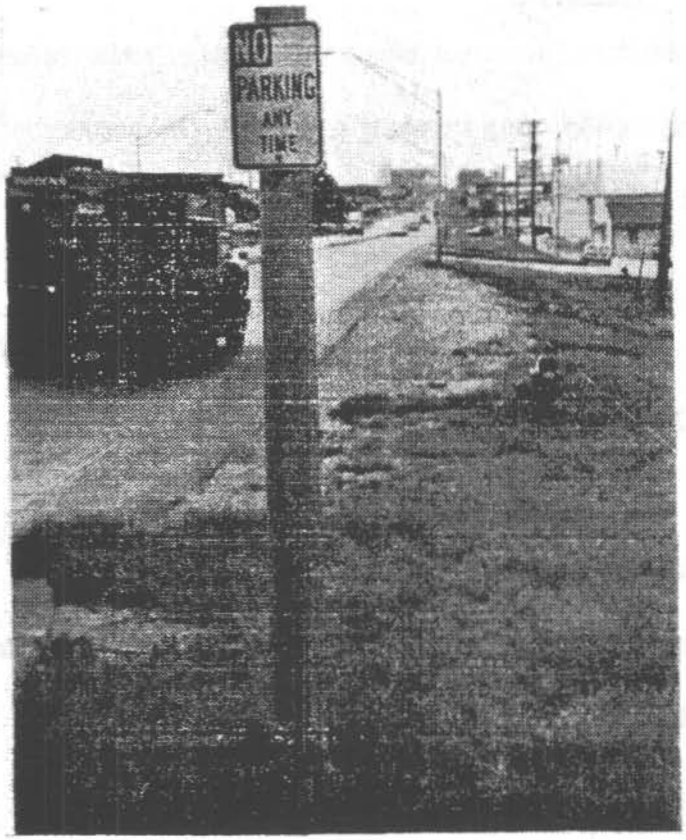


FIGURE 12. PHOTOGRAPHS OF THE WEST "O" ST. SAFETY IMPROVEMENT PROJECT.

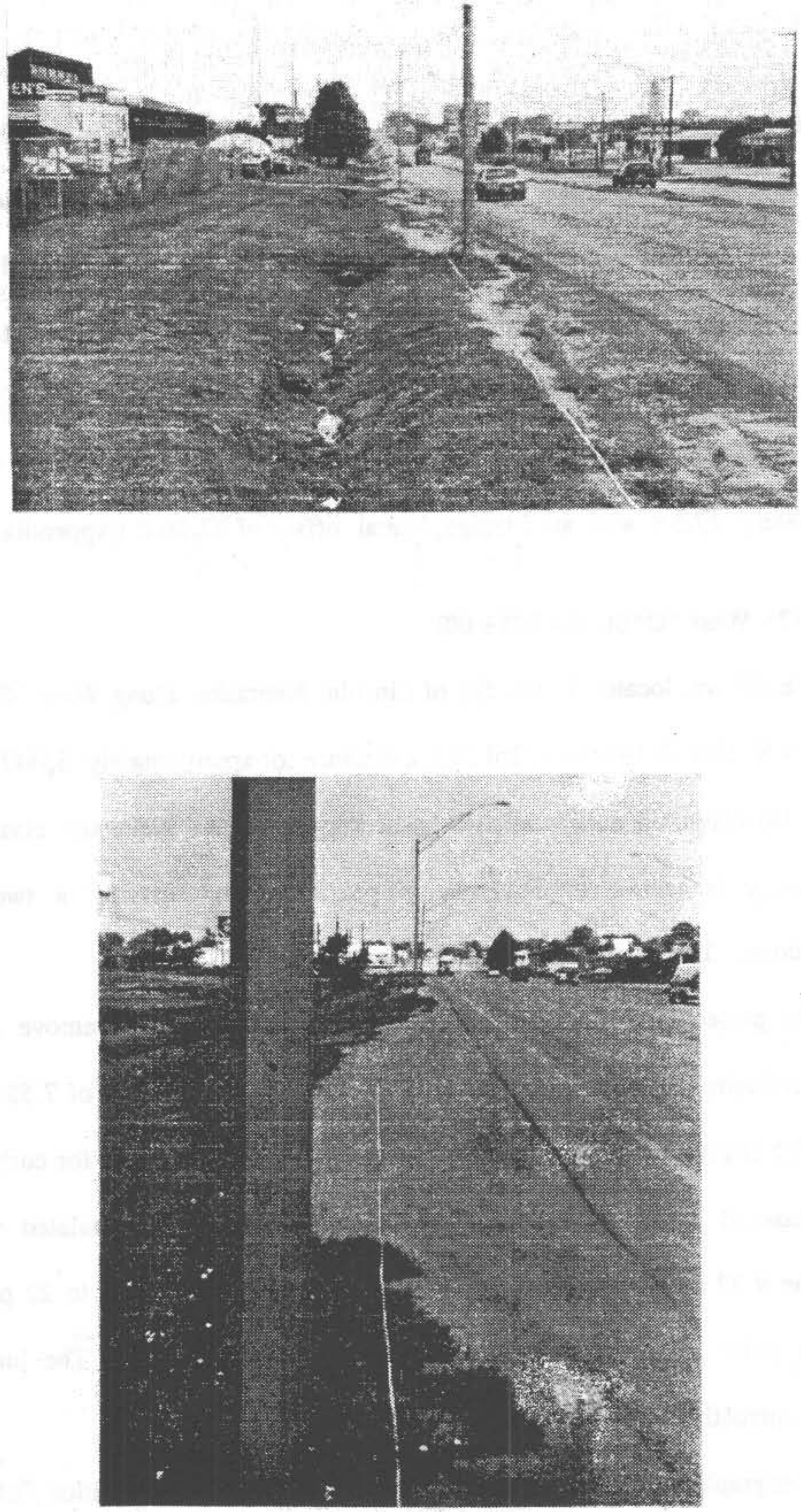


FIGURE 13. PHOTOGRAPHS OF THE WEST "O" ST. SAFETY IMPROVEMENT PROJECT.

The actual accident experience before the implementation of the project for the existing light poles was 5 accidents over a period of 8.33 years or 0.60 accidents per year. The accident severity was 4 PDO's (80%), 1 injury accident (20%), and 0 fatal accidents (0%) from January 1, 1982 to April 30, 1990. The ADT before the project began was found to be 22,900 in 1989. The expected average annual traffic growth rate was 3%. The roadside coverage factor of the fixed objects for the "before" site conditions was found to be approximately 17.5% with an average lateral offset of 12.36 ft (Appendix J).

7.7 Site #7: West "O" St. (to 241+00)

Site #7 was located in the city of Lincoln, Nebraska, along West "O" St. from Station 211+00 to Station 241+00 (N. 3rd St.), a distance of approximately 3,000 ft (0.57 mi.). The street is also classified as a municipal state highway in the Nebraska classification system. The roadway is known as Highway US 6, which is currently a two-way, four-lane, curbed-section. The posted speed limit was 40 mph.

The project which will be implemented at this site will remove and relocate the existing luminaires or light supports from an average lateral offset of 7.52 ft to some future offset which is greater than or equal to the current standard of 6 ft for curbed sections. The actual measured average lateral offset of the luminaires was calculated from the project plans to be 9.32 ft. The number of poles will be reduced from 23 to 22 poles, including 2 obstructed poles for both the "before" and "after" site conditions. The luminaires or light poles are currently located on both sides of the roadway.

Photographs of the roadway section before the implementation of the project are shown in Figure 14. The projected costs of the improved and/or new lighting are as follows:

FIGURE 14. PHOTOGRAPHS OF THE WEST "O" ST. SAFETY IMPROVEMENT PROJECT.

Installation Costs:	$13,600 (17 x $800)
Installation Costs:	$ 8,000 (5 x $1,600) arm pole
Removal Costs:	$ 5,200 (16 x $325)
Total:	$26,800

The ADT in 1989 was 25,800; the expected average annual traffic growth rate was 3%. The roadside coverage factor of the fixed objects for the "before" site conditions was approximately 21.7% with an average lateral offset of 5.54 ft (Appendix J).

8 "UPACE"SITE ANALYSES

The seven previously described roadway sections were analyzed using the "UPACE" computer model (18,20). The benefit-to-cost ratio analyses were performed with the site-specific roadway section data for each of the seven field locations. The analysis for each site involved varying the lateral offset of the poles in order to evaluate the minimum acceptable lateral obstacle offset from the cost-effectiveness or benefit-to-cost ratio standpoint.

8.1 Site #1: East "O"St.

The site-specific computer inputs for the computer model are as follows:

Roadway Width:	48 ft
Speed Limit:	40 mph
Roadway Cross-Section:	Two-Way, Four-Lanes, Curbed
Area Type:	Urban
Roadside Coverage Factor:	60.5%
Average Fixed Object Offset:	10.12 ft
Pole Offset (before):	2.25 ft
Pole Offset (after):	7.57 ft
Pole Configuration:	Both Sides
Number of Poles:	167 (before)
	103 (after)
	70 (able to be impacted)
Pole Type:	Metal
Base Year ADT:	30,035
Traffic Growth:	2.5%
Actual Accident Experience:	8.40 accidents per year
Project Cost:	$625,882.62
Project Life:	15 years
Interest Rate:	10%

The actual accident data experience revealed that there were 8.40 accidents per year along the roadway section. The accident predictive model estimated that there would be approximately 8.63 accidents per year. The actual accident data experience after implementation of the project revealed that there were 2.44 accidents per year. The accident predictive model suggested that there would be approximately 2.73 accidents per year at the 8 ft final lateral pole offset. Thus, the accident predictive model performed reasonably well.

The first step of the analysis of Site #1 was to run the scenario which was implemented in the field, involving the reduction of light poles and the relocation of the light poles from approximately 2 ft to 8 ft. The initial computer analysis also included runs varying the increase of the lateral offset to the final positions of 3 ft through 10 ft in 1 ft increments. The computer analysis was performed for both the actual accident data and accident predictive model developed by Zegeer and Parker (32). The analysis showed a close correlation between actual and predictive accident data:

Distance of Light Poles from Curb		Benefit-To-Cost Ratio	
		Accident Data	
Before	After	Actual	Predictive
2 ft	3 ft	0.736	0.756
2 ft	4 ft	0.926	0.951
2 ft	5 ft	1.059	1.088
2 ft	6 ft	1.158	1.189
2 ft	7 ft	1.239	1.273
2 ft	8 ft*	1.304*	1.340*
2 ft	9 ft	1.360	1.397
2 ft	10 ft	1.406	1.444

* - actual case performed in field

These benefit-to-cost ratios indicate that it would have been cost-effective to relocate the luminaires to a minimum 5 ft lateral offset from the curb, as shown in Figure 15. The current standards for lateral offset for this situation are a minimum of 6 ft from the curb. The actual field installation was located at an average lateral offset of 8 ft because of the existence of a sidewalk.

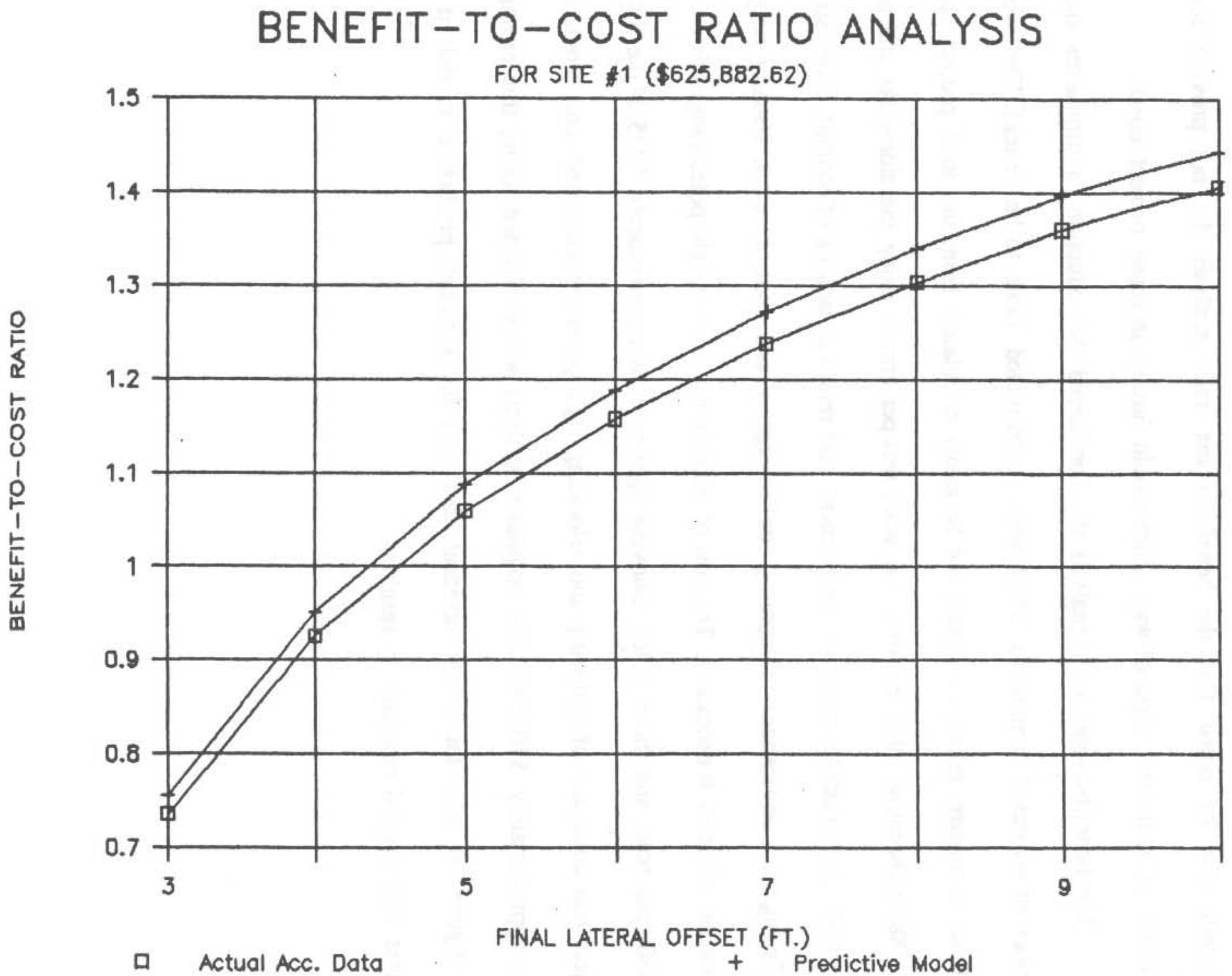


FIGURE 15. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #1 ($625,882.62).

The benefit-to-cost ratios plotted in Figure 15 increase at a decreasing rate and begin to level off at a final lateral offset of 10 ft and greater. Thus, there would be no significant increase in benefit for any additional increase in the lateral offset beyond 10 ft; in addition, it should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way which would further increase project costs.

The benefit-to-cost ratio analysis also considered the reduction in luminaires and the number of relocated luminaires which were unobstructed (able to be struck). The average cost per luminaire relocation could not be easily calculated from the total project cost of $625,882.62 because other construction work was performed along the sidewalks and under the streets (for example, concrete replacement and removal, jacking of conduit under streets, traffic signal modifications, temporary traffic signing and control, etc.). Usually only the relocation of poles is necessary. The cost of relocation of metal light poles ranges from $500 to $800 per pole, and the cost for removing light poles is approximately $325. If the Site #1 project had consisted of removing and relocating light poles the estimated cost would have been approximately $103,000. The computer analysis was performed using this estimated cost figure for both the actual accident data and the accident predictive model; it was evident that a good comparison resulted.

The results of this analysis showed the following:

Distance of Light Poles From Curb		Benefit-To-Cost Ratio	
		Accident Data	
Before	After	Actual	Predictive
2 ft	3 ft	4.473	4.594
2 ft	4 ft	5.628	5.781
2 ft	5 ft	6.437	6.612
2 ft	6 ft	7.037	7.228
2 ft	7 ft	7.531	7.736
2 ft	8 ft*	7.927*	8.142*
2 ft	9 ft	8.264	8.488
2 ft	10 ft	8.541	8.773

* - actual case performed in field

These benefit-to-cost ratios indicate that any one of the relocation countermeasures would have been cost-effective. Under these circumstances, it would be difficult to evaluate the current lateral obstacle clearance policies since all of the benefit-to-cost ratios are greater than 1.0, as shown in Figure 16.

The results plotted in Figure 16 show that the benefit-to-cost ratios increased at a decreasing rate, indicating that at some point the increase in benefit would be negligible for any increase in the final lateral offset position. This occurred at a distance of 10 ft and greater. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way, which would further increase project costs.

The pole density was 41.2 poles per mile based on 103 luminaires, and 28.4 poles per mile based upon 70 unobstructed luminaires. The calculations were based on actual field measurements. If additional computer runs would be needed at various ADT's, the predictive model would be able to properly estimate the new expected accidents for the various ADT's.

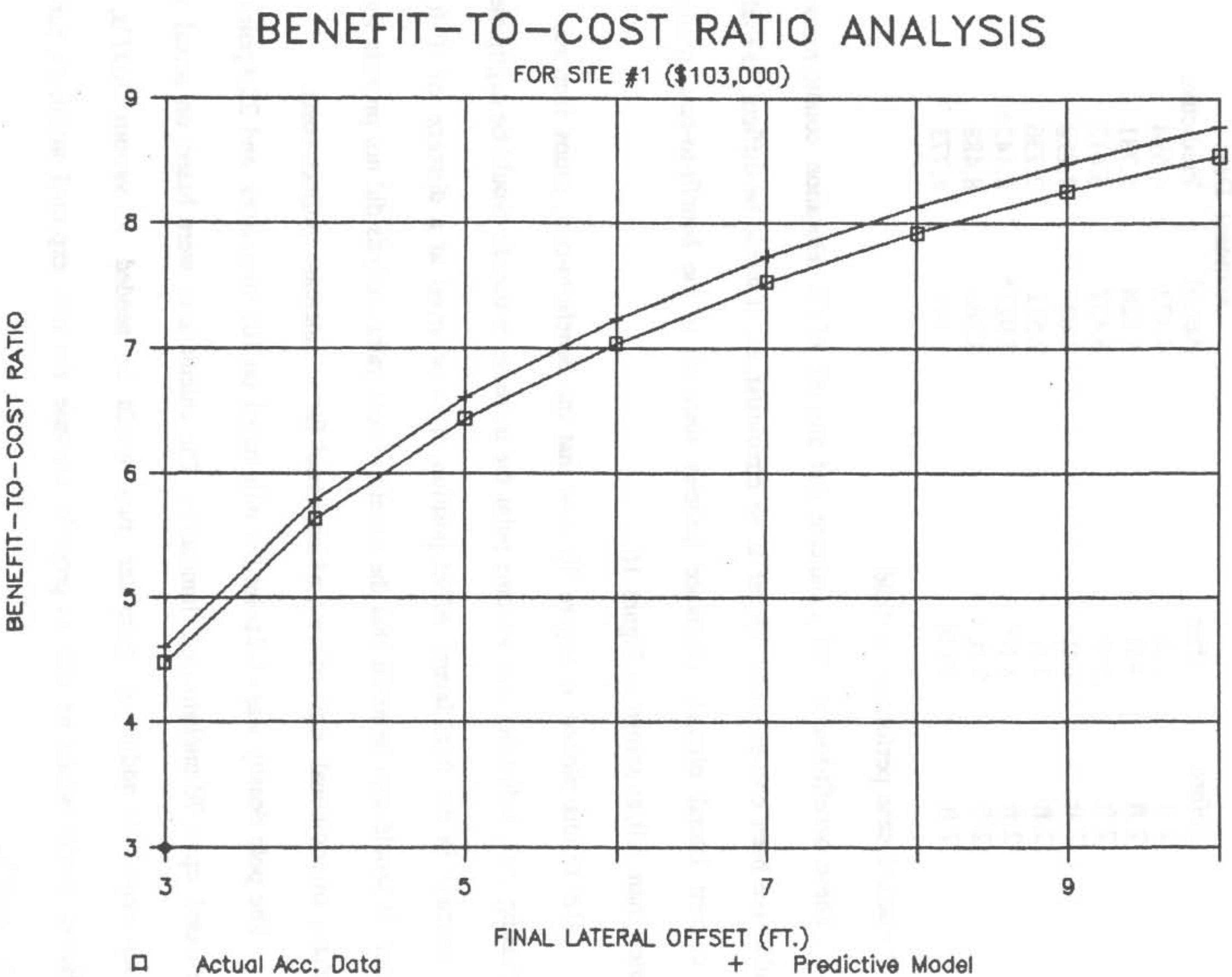


FIGURE 16. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #1 ($103,000).

8.2 Site #2: West 7th St.

The site-specific computer inputs for the computer model are as follows:

Roadway Width:	30 ft
Speed Limit:	30 mph
Roadway Cross-Section:	Two-Way, Two-Lanes, Curbed
Area Type:	Urban
Roadside Coverage Factor:	59.3%
Average Fixed Object Offset:	9.39 ft
Pole Offset (before):	2.44 ft
Pole Offset (after):	9.67 ft
Pole Configuration:	One Side
Number of Poles:	9 (before) 9 (after)
Pole Type:	Wood
Base Year ADT:	5,480
Traffic Growth:	2.0%
Actual Accident Experience:	Minimal (Use Predictive Model)
Project Cost:	$5,299.12
Project Life:	20 years
Interest Rate:	8%

The first step of the analysis of Site #2 was to run the scenario which was implemented in the field involving the relocation of both utility and light poles from approximately 2 ft to 10 ft. The initial computer analysis also included runs varying the increase of the lateral offset to the final positions of 3 ft through 10 ft in 1 ft increments. The computer analysis was performed using the accident predictive model developed by Zegeer and Parker (32).

Only a few PDO accidents had occurred before the project was implemented, raising the question of whether the pole relocations were necessary from a safety point of view.

The results of the analysis revealed the following:

Distance of Poles From Curb		Benefit-To-Cost Ratio
		Accident Data
Before	After	Predictive
2 ft	3 ft	2.605
2 ft	4 ft	4.623
2 ft	5 ft	5.961
2 ft	6 ft	6.907
2 ft	7 ft	7.649
2 ft	8 ft	8.226
2 ft	9 ft	8.699
2 ft	10 ft*	8.764*

* - actual case performed in field

From the benefit-to-cost ratios presented above, it is evident that a relocation of the utility and light poles would have been very effective with respect to the costs required to complete the project. All of the relocation countermeasures had benefit-to-cost ratios greater than 1.0, as shown in Figure 17. Under these circumstances it would be difficult to evaluate the current lateral obstacle clearance policies.

If a situation such as this were to occur (i.e., all relocation countermeasures produce high benefit-to-cost ratios combined with a low actual accident experience), would a relocation of any lateral distance be required? It does not seem practical to relocate poles from 2 ft to 3 ft even though it would be very cost-effective. Thus, the current pole locations may be adequate in this instance; however, if highway construction crews make other roadway improvements or modifications at this site in the future, it would seem reasonable to move the poles at the that time.

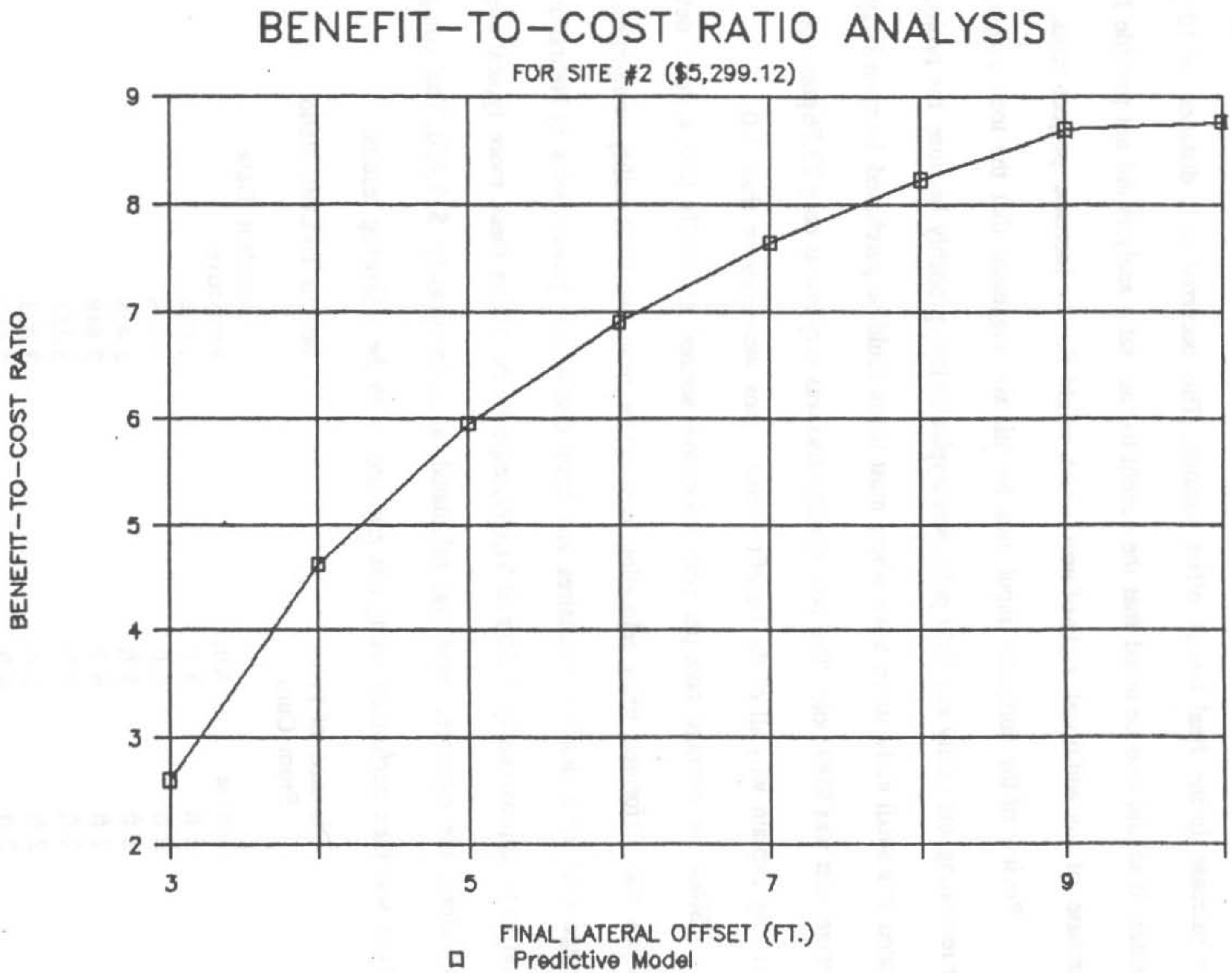


FIGURE 17. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #2 ($5,299.12).

The results plotted in Figure 17 show that the benefit-to-cost ratios increased at a decreasing rate, indicating that at some point the increase in benefit would be negligible for any increase in the final lateral offset position. This occurred at a distance of 10 ft and greater. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of any additional right-of-way, which would further increase project costs.

Review of the computer input data for this site suggested that the total project cost for relocating the utility and light poles was atypically low, probably because the project was located in a small midwestern town where most items could be purchased inexpensively. The average cost was $589/pole. The pole density also was very low at only 23.76 poles per mile. This may explain why all of the benefit-to-cost ratios were greater than 1.0.

Since the average cost per pole relocation seemed atypically low, a more detailed analysis was performed using relocation cost values from two local utility companies. The average cost for relocating luminaires and basic distribution power poles in Nebraska was found to be approximately $650 and $1,650, respectively. Using these more typical average cost values, the estimated cost was calculated at approximately $12,850. The computer analysis was then performed using this estimate, with the following results:

Distance of Poles From Curb		Benefit-To-Cost Ratio
Before	After	Accident Data Predictive
2 ft	3 ft	1.074
2 ft	4 ft	1.906
2 ft	5 ft	2.458
2 ft	6 ft	2.848
2 ft	7 ft	3.154
2 ft	8 ft	3.392
2 ft	9 ft	3.587
2 ft	10 ft*	3.614*

* - actual case performed in field

These benefit-to-cost ratios indicate that any of the relocation countermeasures would have been effective. Under these circumstances, it would be difficult to evaluate the current lateral obstacle clearance policies since all of the benefit-to-cost ratios were greater than 1.0, as shown in Figure 18.

The results plotted in Figure 18 show that the benefit-to-cost ratios increased at a decreasing rate, indicating that at some point the increase in benefit would be negligible for any increase in the final lateral offset position. This occurred at a distance of 10 ft and greater. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way, which would further increase project costs.

8.3 Site #3: East 7th St.

The site-specific computer inputs for the computer model are as follows:

Roadway Width:	30 ft
Speed Limit:	30 mph
Roadway Cross-Section:	Two-Way, Two-Lanes, Curbed
Area Type:	Urban
Roadside Coverage Factor:	58.0%
Average Fixed Object Offset:	8.91 ft
Pole Offset (before):	3.00 ft
Pole Offset (after):	10.25 ft
Pole Configuration:	Both Sides
Number of Poles:	9 (before) 9 (after)
Pole Type:	Wood
Base Year ADT:	5,480
Traffic Growth:	2.0%
Actual Accident Experience:	Minimal (Use Predictive Model)
Project Cost:	$3,372.10
Project Life:	20 years
Interest Rate:	8%

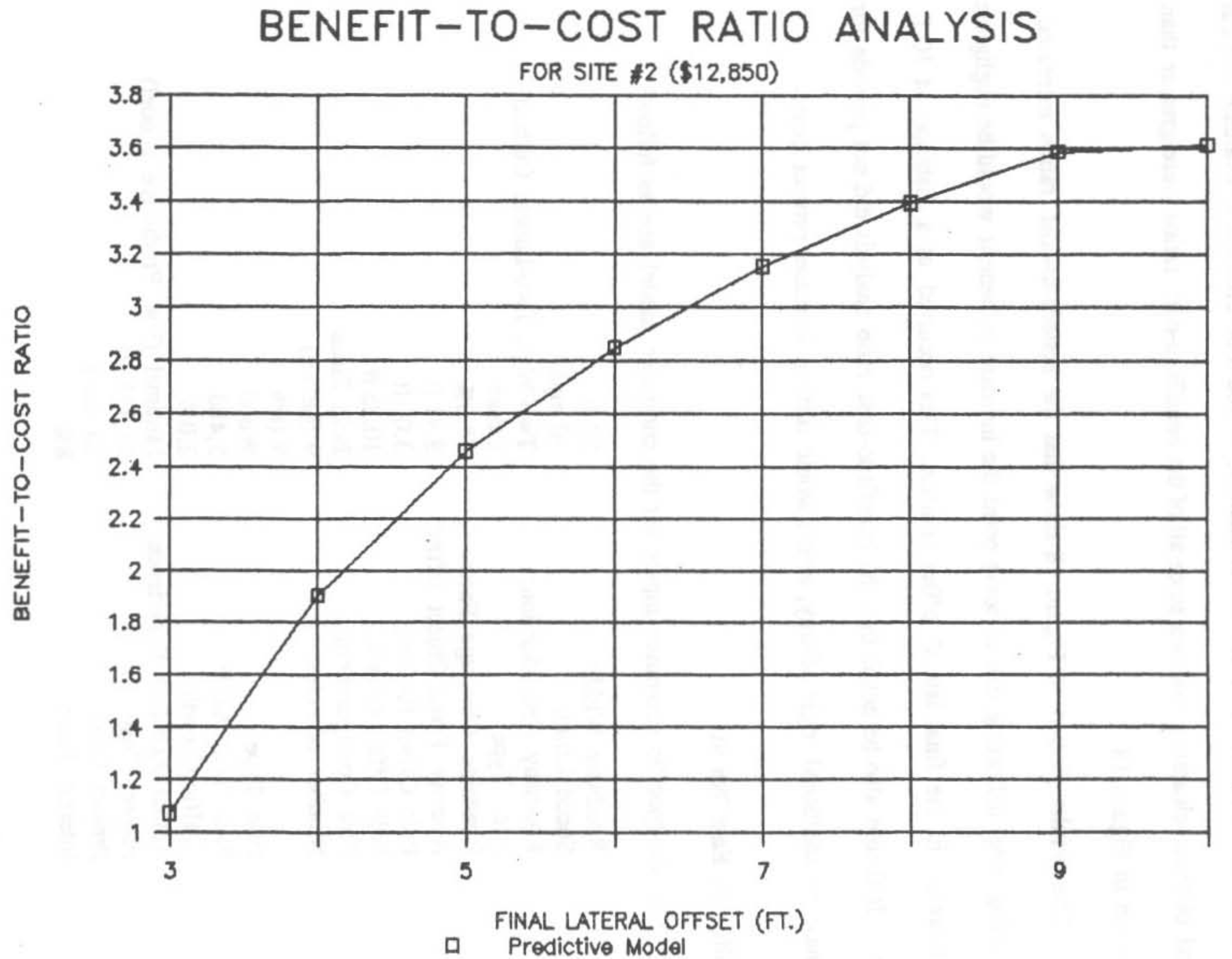


FIGURE 18. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #2 ($12,850).

The first step of the analysis of Site #3 was to run the scenario for this project, involving the relocation of utility and light poles from approximately 3 ft to 10 ft. The initial analysis also included runs varying the increase of the lateral offset to the final positions of 4 ft through 10 ft in 1 ft increments. The computer analysis was performed using the accident predictive model developed by Zegeer and Parker (32).

Only a few PDO accidents had occurred before the project was implemented, raising the question of whether the pole relocations were necessary from a safety point of view.

The results of the analysis revealed the following:

Distance of Poles From Curb		Benefit-To-Cost Ratio
		Accident Data
Before	After	Predictive
3 ft	4 ft	0.955
3 ft	5 ft	2.971
3 ft	6 ft	4.338
3 ft	7 ft	5.473
3 ft	8 ft	6.322
3 ft	9 ft	7.023
3 ft	10 ft*	7.241*

* - actual case performed in field

The benefit-to-cost ratios indicate that it would have been cost-effective to relocate the utility and light poles to a minimum 5 ft lateral offset from the curb, as shown in Figure 19. The results plotted in Figure 19 show that the benefit-to-cost ratios increased at a decreasing rate, indicating that at some point the increase in benefit would be negligible for any increase in the final lateral offset position. This point occurred at a distance of 10 ft and greater. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way which would further increase project costs.

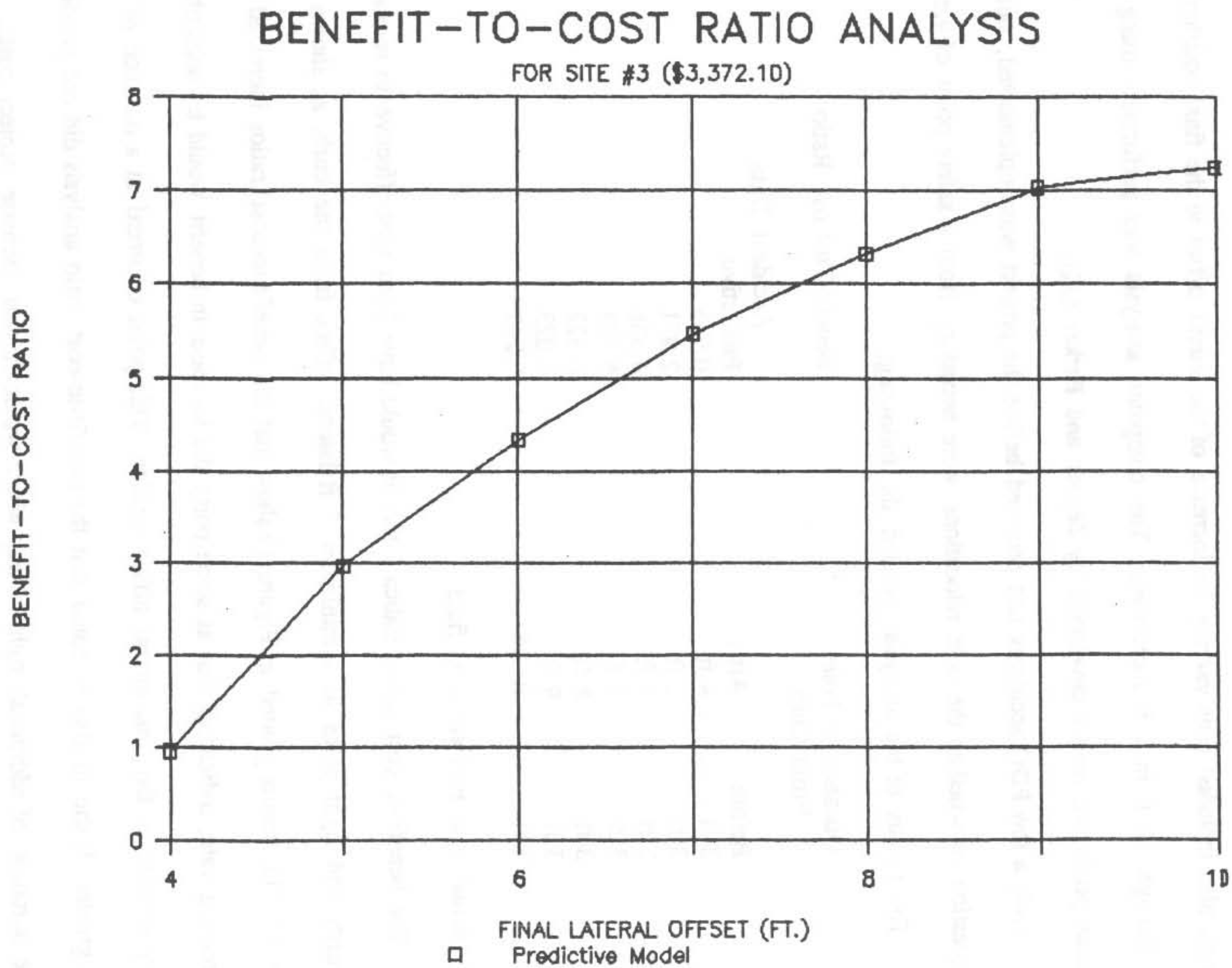


FIGURE 19. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #3 ($3,372.10).

With the exception of the first relocation countermeasure at Site #3, the benefit-to-cost ratios at Sites #2 and #3 were all greater than 1.0. This first countermeasure involved relocating from a distance of 3 ft from the curb to 4 ft. One possible explanation for a benefit-to-cost ratio of below 1.0 is that the relocation was only 1 ft, and the original offset was 3 ft rather than 2 ft as in Site #2.

Review of the computer input data for this site suggested that the total project cost for relocating the utility and light poles was atypically low, probably because the project was located in a small midwestern town where most items could be purchased inexpensively. The average cost per pole was $375/pole, and the pole density was very low at only 33.94 poles per mile. These factors may explain why almost all of the benefit-to-cost ratios were significantly greater than 1.0.

Since the average cost per pole relocation seemed atypically low, a more detailed analysis was performed using more typical relocation cost values from two local utility companies. The average cost for relocating luminaires and basic distribution power poles in Nebraska was found to be approximately $650 and $1,650, respectively. Using more typical average cost values, the estimated cost would have been approximately $11,850. The computer analysis was then performed using this estimate, with the following results:

Distance of Poles From Curb		Benefit-To-Cost Ratio
		Accident Data
Before	After	Predictive
3 ft	4 ft	0.272
3 ft	5 ft	0.845
3 ft	6 ft	1.234
3 ft	7 ft	1.557
3 ft	8 ft	1.799
3 ft	9 ft	1.998
3 ft	10 ft*	2.061*

* - actual case performed in field

These benefit-to-cost ratios indicate that it would have been cost-effective to relocate the utility and light poles to a minimum 6 ft lateral offset from the curb, as shown in Figure 20. The current standards for lateral offset for this situation are a minimum of 6 ft from the curb; the actual field installation was located at an average lateral offset of 10 ft.

The results plotted in Figure 20 show that the benefit-to-cost ratios increased at a decreasing rate, indicating that at some point the increase in benefit would become negligible for any increase in the final lateral offset position. This point occurred at a distance of 10 ft and greater. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way which would further increase project costs.

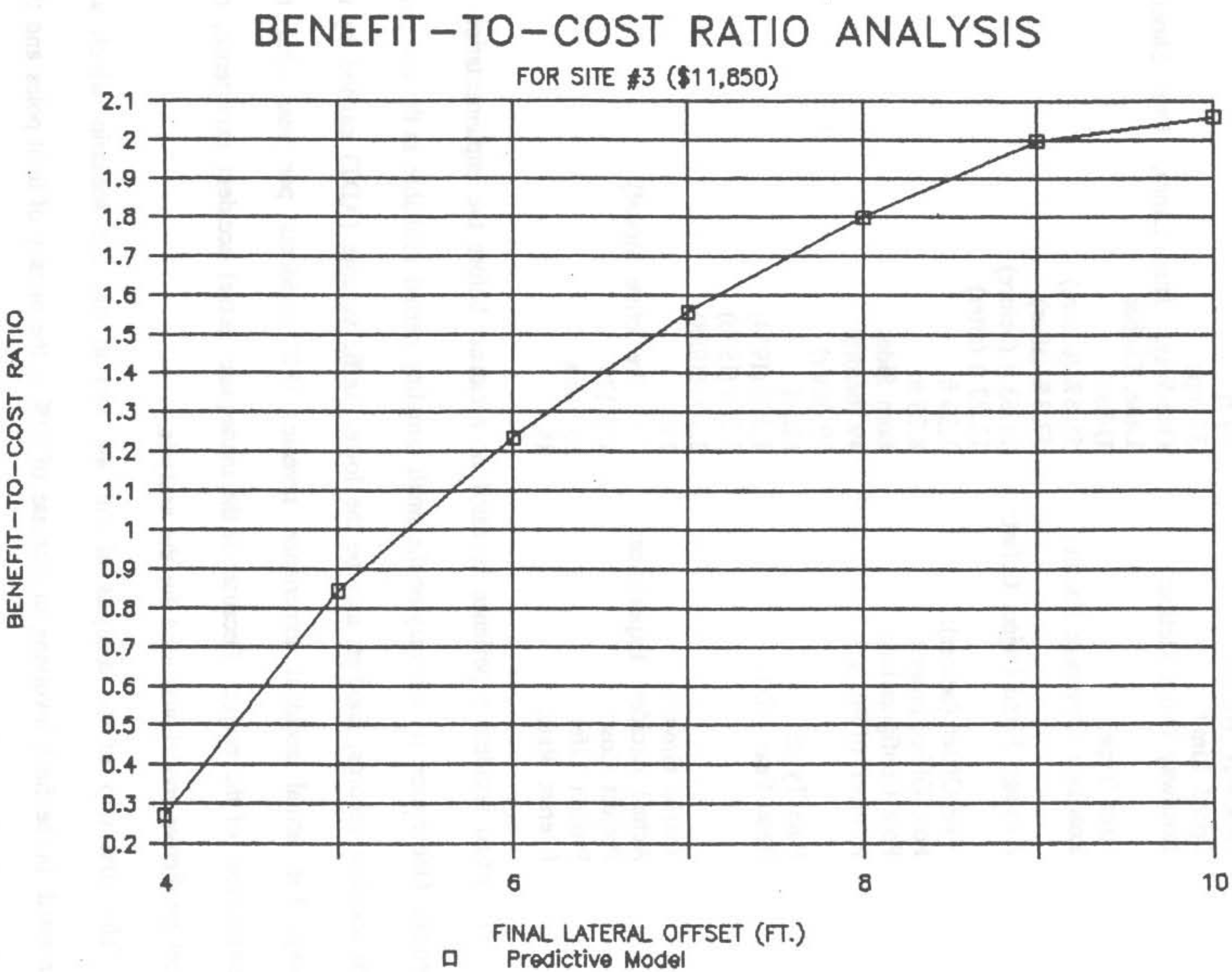


FIGURE 20. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #3 ($11,850).

8.4 Site #4: Florence Blvd.

The site-specific computer inputs for the computer model are as follows:

Roadway Width:	39 ft
Speed Limit:	35 mph
Roadway Cross-Section:	One-Way, Three-Lanes, One Shoulder Lane, Curbed
Area Type:	Urban
Roadside Coverage Factor:	55.6% (before) 57.3% (after)
Average Fixed Object Offset:	11.53 ft (before) 12.22 ft (after)
Pole Offset (before):	3.39 ft
Pole Offset (after):	8.25 ft
Pole Configuration:	Both Sides
Number of Poles:	49 (before) 59 (after)
Pole Type:	Metal
Base Year ADT:	4,800 (1984) 3,000 (1986) 2,900 (1988)
Traffic Growth:	2%
Actual Accident Experience:	(Use Predictive Model)
Project Cost:	$63,125
Project Life:	20 years
Interest Rate:	8%

The actual accident experience revealed no accidents before the implementation of the project. One reason for this may be the small sampling period available in the computer system accident records, another may be the lower traffic volume (ADT) carried by the roadway. The actual accident experience revealed 0.27 accidents per year after the implementation of the project. Because of the inadequate actual accident experience, the accident predictive model was used for the analysis.

The first step of the analysis of Site #4 was to run the scenario which was implemented in the field, involving an increase of 20% in the density of light poles and the relocation of the light poles from approximately 3 ft to 8 ft. The initial computer analysis also included runs varying the increase of the lateral offset to the final positions of 4 ft through 13 ft in 1 ft increments. The computer analysis was performed using the accident predictive model developed by Zegeer and Parker (32). The results of this analysis revealed the following:

Distance of Light Poles From Curb		Benefit-To-Cost Ratio
		Accident Data Predictive
Before	After	
3 ft	4 ft	0.016
3 ft	5 ft	0.342
3 ft	6 ft	0.575
3 ft	7 ft	1.158
3 ft	8 ft*	1.376*
3 ft	9 ft	1.554
3 ft	10 ft	1.702
3 ft	11 ft	1.829
3 ft	12 ft	1.939
3 ft	13 ft	2.035

* - actual case performed in the field

From the benefit-to-cost ratios presented above, it was evident that it would have been cost effective to relocate the luminaires to a minimum 7 ft lateral offset from the curb, as shown in Figure 21. The current standards for lateral offset for this situation are a minimum of 6 ft from the curb. The actual field installation was located at an average lateral offset of 8 ft due to the existence of a sidewalk.

The benefit-to-cost ratios plotted in Figure 21 increased at a decreasing rate and began to level off at a final lateral offset of 12 ft and greater. This indicates there would be no significant increase in benefit for any additional increase in lateral offset beyond 12 ft. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way which would further increase project costs.

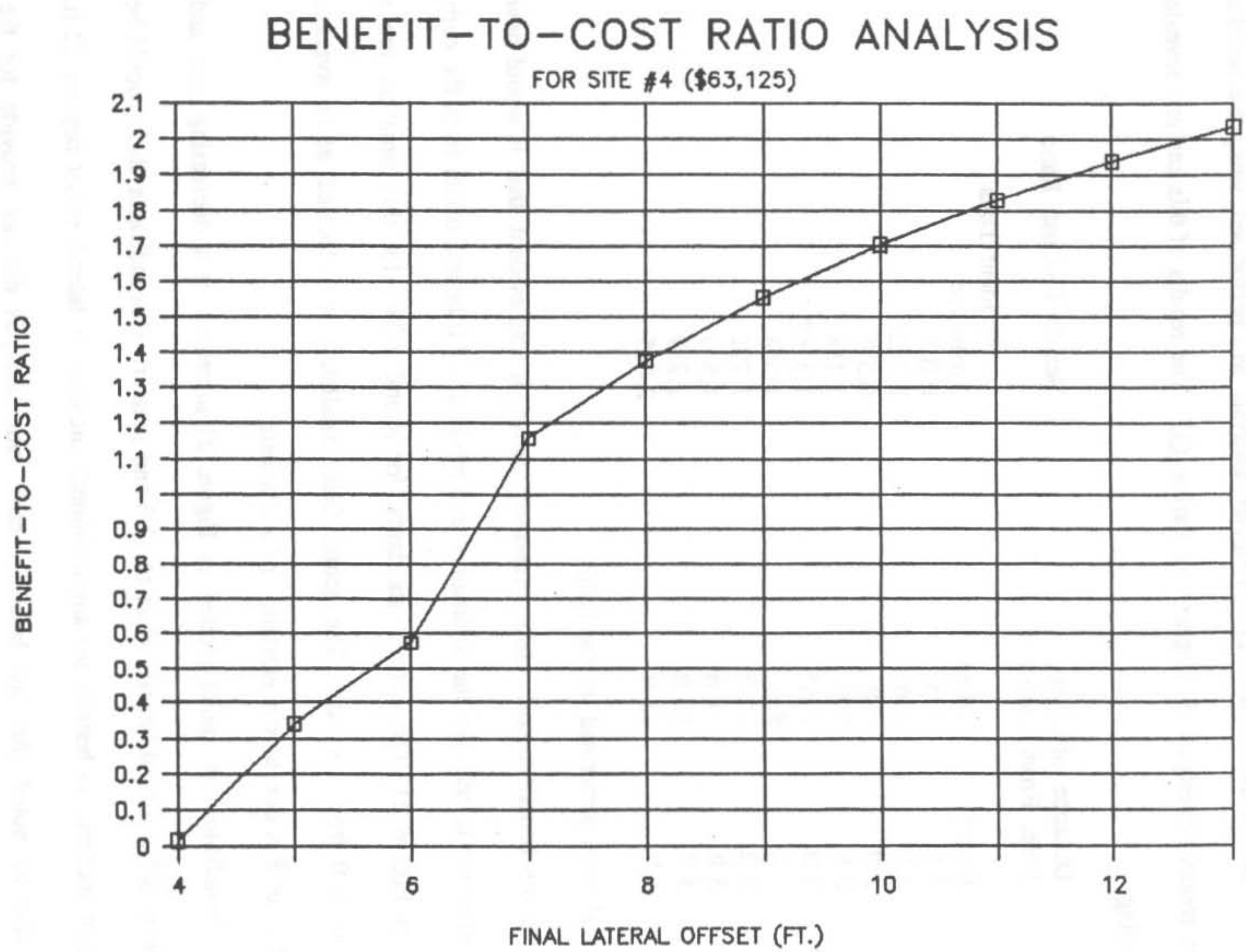


FIGURE 21. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL OFFSET FOR SITE#4 ($63,125).

The estimated relocation and installation costs of the light poles were determined by examining the original site survey plans to count the number of poles which were to be removed. The number and location of the new light poles was determined from our field visit after implementation of the project. Using the costs described above in the Site #1 analysis, the relocation and installation costs would be approximately $63,125.

8.5 Site #5: 36th St.

The site-specific computer inputs for the computer model are as follows:

Roadway Width:	37 ft
Speed Limit:	30 mph
Roadway Cross Section:	Two-Way, Two-Lanes, One Center Turn-Lane, Curbed
Area Type:	Urban
Roadside Coverage Factor:	63.0% (before) 56.0% (after)
Average Fixed Object Offset:	11.56 ft (before) 15.04 ft (after)
Pole Offset (before):	3.25 ft
Pole Offset (after):	9.31 ft
Pole Configuration:	Both Sides (before) One Side (after)
Number of Poles:	20 (before) 13 (after)
Pole Type:	Metal
Base Year ADT:	7,200
Traffic Growth:	2%
Actual Accident Experience:	(Use Predictive Model)
Project Cost:	$231,000
Project Life:	20 years
Interest Rate:	8%

The actual accident experience showed no accidents before the implementation of the project. One reason for this may be the small sampling period available in the computer system accident records, another may be the lower traffic volume (ADT) carried by the roadway. The actual accident experience revealed no accidents after the implementation of the project. Because of the inadequate actual accident experience, the accident predictive model was used for the analysis.

The first step of the analysis of Site #5 was to run the scenario which was implemented in the field, involving a 35% reduction in the density of light and utility poles by undergrounding the utility lines and relocating the light poles from approximately 3 ft to 13 ft. The initial computer analysis also included runs varying the increase of the lateral offset to the final positions of 4 ft through 13 ft in 1 ft increments. The computer analysis was performed using the accident predictive model developed by Zegeer and Parker (32). The results of this analysis revealed the following:

Distance of Poles From Curb		Benefit-To-Cost Ratio
		Accident Data
Before	After	Predictive
3 ft	4 ft	0.204
3 ft	5 ft	0.249
3 ft	6 ft	0.281
3 ft	7 ft	0.306
3 ft	8 ft	0.326
3 ft	9 ft*	0.342*
3 ft	10 ft	0.356
3 ft	11 ft	0.367
3 ft	12 ft	0.377
3 ft	13 ft	0.386

* - actual case performed in the field

These benefit-to-cost ratios indicate that it would not have been cost-effective to relocate the light poles to any increased lateral offset with the undergrounding of the utility lines, as shown in Figure 22. The current standards for lateral offset for this situation are a minimum of 6 ft from the curb. The actual field installation (new luminaires or light poles) was located at an average lateral offset of 9 ft due to the existence of a sidewalk.

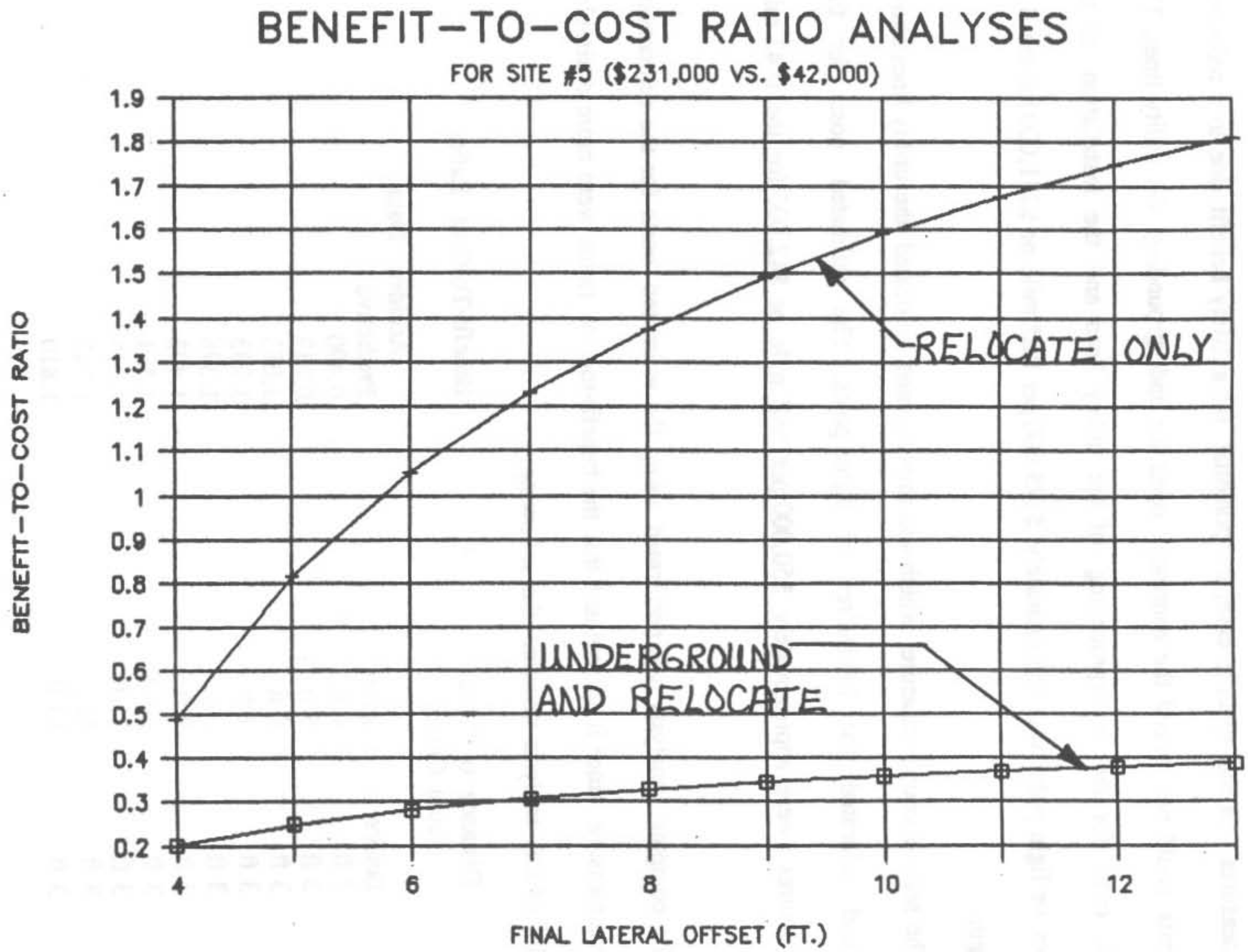


FIGURE 22. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #5 ($231,000 vs. $42,000).

One reason that these ratios are so low is that there was no severe accident problem for which a significant safety benefit could be achieved through the use of cost-effective countermeasures. In this specific case, the potential for a safety benefit due to a reduction in accidents could not exceed the enormous costs for undergrounding the utility lines. The estimated costs for the undergrounding of the utility lines and the installation of the luminaires or light poles was approximately $275,000 per half mile or $231,000 for the 0.42 mile length.

The second countermeasure which was implemented relocated the utility lines above ground and relocated the luminaires or light poles. The estimated costs for this countermeasures were approximately $50,000 per half mile or $42,000 for the 0.42 mile length.

The computer analysis was performed using the estimated costs for the relocation-only countermeasure since it was evident that the benefit-to-cost ratios were more desirable. The results of this analysis revealed the following:

Distance of Poles From Curb		Benefit-To-Cost Ratio
		Accident Data
Before	After	Predictive
3 ft	4 ft	0.490
3 ft	5 ft	0.817
3 ft	6 ft	1.053
3 ft	7 ft	1.233
3 ft	8 ft	1.376
3 ft	9 ft	1.493
3 ft	10 ft	1.591
3 ft	11 ft	1.675
3 ft	12 ft	1.747
3 ft	13 ft	1.810

These benefit-to-cost ratios indicate that it would have been cost-effective to relocate the luminaires to a minimum 6 ft lateral offset from the curb, as shown in Figure 22. The current standards for lateral offset for this situation are a minimum of 6 ft from the curb.

The benefit-to-cost ratios plotted in Figure 22 increased at a decreasing rate and began to level off at a final lateral offset of 10 ft and greater, indicating that there would be no significant increase in benefit for any additional increase in lateral offset beyond 10 ft. The incremental increase of benefit was less than 0.10 beyond the 10 ft lateral offset. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way which would further increase project costs.

Despite the negative benefit-to-cost ratio, the undergrounding option was selected for implementation in the field. Mike Daniels of the Omaha Public Power District stated in a telephone conversation that three considerations influenced the selection of this option:

(1) When utility lines are being relocated, there is always concern for the problems which may arise in moving the aerial facilities to a new location. Also, buildings often are positioned where the newly relocated poles should be relocated.

(2) Even when utility facilities are located on public right-of-way, utility companies must seriously consider the wishes of the property owner. Political pressures may lead to decisions which are not economical from a benefit-to-cost perspective.

(3) When roadway projects involving utilities are being planned, the underground countermeasure of utility lines is always a viable alternative for consideration. Despite the higher implementation costs than relocation-only options, undergrounding does have a higher potential for reducing accidents.

8.6 Site #6: West "O" St. (to 211+00)

The site-specific computer inputs for the computer model are as follows:

Roadway Width:	55 ft
Speed Limit:	40 mph
Roadway Cross-Section:	Two-Way, Four-Lanes, Non-Curbed (before), Curbed (after)
Area Type:	Urban
Roadside Coverage Factor:	17.5%
Average Fixed Object Offset:	12.36 ft
Pole Offset (before):	8.00 ft
Pole Offset (after):	8.82 ft
Pole Configuration:	Both Sides
Number of Poles:	34 (before) 22 (after)
Pole Type:	Metal
Base Year ADT:	22,900
Traffic Growth:	3%
Actual Accident Experience:	0.60 accidents per year
Project Cost:	$30,250
Project Life:	20 years
Interest Rate:	8%

The actual accident experience revealed that there were 0.60 accidents per year along the roadway section. The accident predictive model estimated that there would be approximately 0.73 accidents per year. Thus, the accident predictive model was assumed to be an adequate indicator of the accident experience after the project was to be implemented.

The first step of the analysis of Site #6 was to run the scenario which is to be implemented in the field, involving a 35% reduction in the density of light poles and the relocation of the light poles from approximately 8 ft to 9 ft. The initial computer analysis also included runs varying the increase of the lateral offset from 9 ft to 18 ft in 1 ft increments. The computer analysis was performed for both the actual accident data and accident predictive model developed by Zegeer and Parker (32). It was evident that an adequate comparison resulted. The results of this analysis revealed the following:

Distance of Light Poles From Road		Benefit-To-Cost Ratio	
		Accident Data	
Before+	After	Actual	Predictive
8 ft	9 ft*	1.088*	0.890*
8 ft	10 ft	1.378	1.127
8 ft	11 ft	1.634	1.337
8 ft	12 ft	1.870	1.530
8 ft	13 ft	2.054	1.680
8 ft	14 ft	2.217	1.814
8 ft	15 ft	2.364	1.934
8 ft	16 ft	2.496	2.042
8 ft	17 ft	2.615	2.139
8 ft	18 ft	2.724	2.228

+ - measured from edge of driving lane
* - actual case calculated from proposed project plans

Benefit-to-cost ratios for the actual accident data indicate that it would have been cost-effective to relocate the luminaires to a minimum 9 ft lateral offset from the edge of the traveled way, as shown in Figure 23. The current standards for lateral offset for this uncurbed, "before" case, situation would vary from 10 ft to 15 ft, depending on whether the roadway was classified as (1) New or Reconstructed Municipal State Highways or (2) Resurfacing, Restoration, and Rehabilitation (3R) Projects on Non-Interstate Municipal State Highways.

Since the "after" case situation is proposed to be a curbed section, only lateral offset options which were 9 ft greater were evaluated in the computer analysis; however, the standards for the curbed "after" case situation require a minimum offset of only 6 ft from back of curb or behind the sidewalk, if applicable.

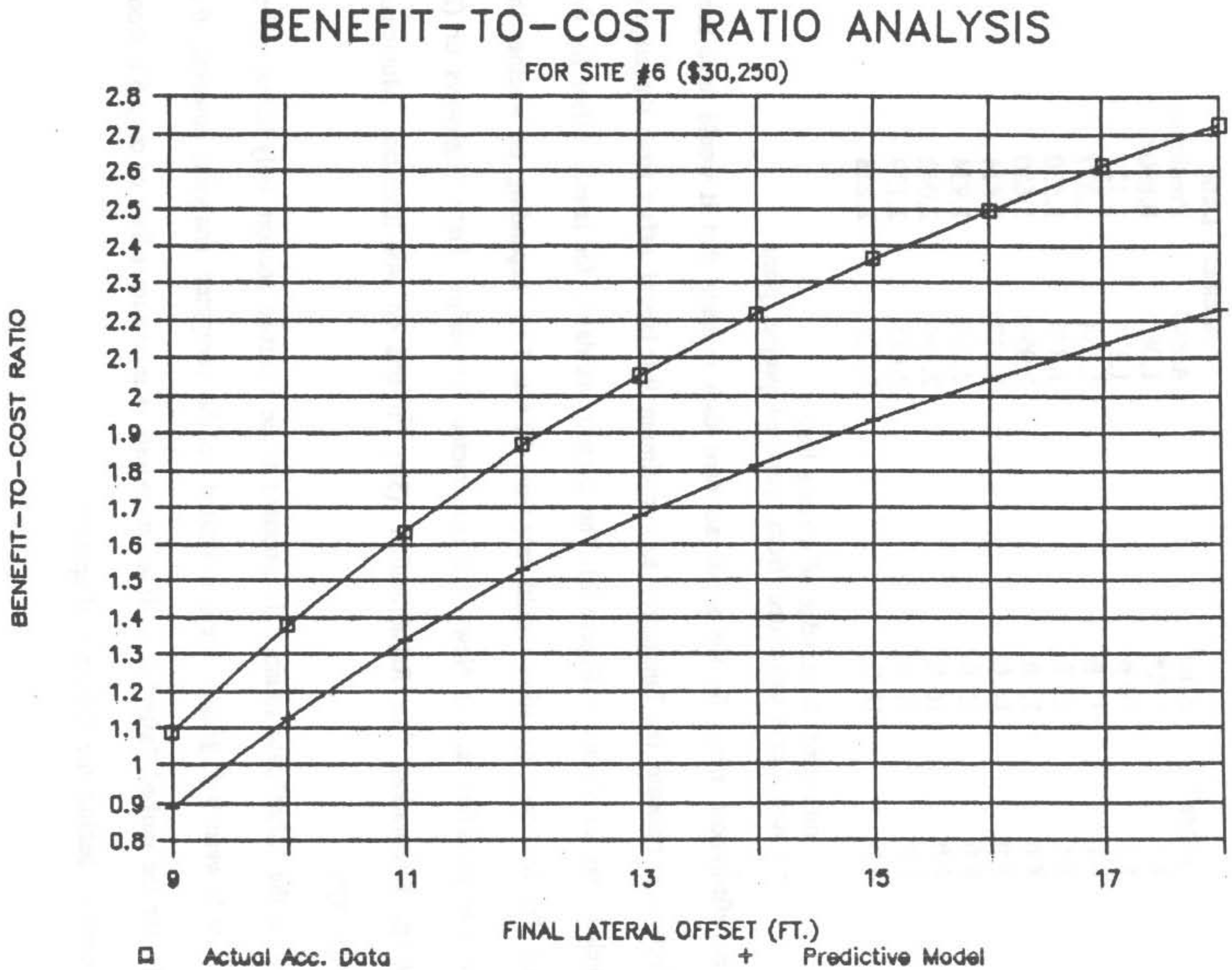


FIGURE 23. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL FOR SITE #6 ($30,250).

Since the poles at Site #6 were already located 8 ft from the edge of the traveled way, it did not seem reasonable to run the computer model for an lateral offset alternative of less than 8 ft (since such an alternative would produce a negative safety benefit).

The benefit-to-cost ratios plotted in Figure 23 increased at a decreasing rate and began to level off at a final lateral offset of 15 ft and greater. However, the benefit-to-cost ratios did not level off as rapidly as the previous sites; one major reason for this may be the lower-than-average roadside coverage factor (the probability of striking a fixed object (obstacle) given that a vehicle runs a specified distance off the road).

Although the benefit-to-cost ratios were greater than 1.0 after a lateral offset of 9 ft, only a small number of accidents had occurred during the "before" case situation. Consequently, it does not seem reasonable to relocate the light poles much farther than the present location. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way, which would further increase project costs.

The estimated relocation and installation costs of the light poles were determined by examining the original site survey plans to count the number of poles which were to be removed. The number and location of the new light poles was determined from our field visit after implementation of the project. Using the costs described in the Site #1 analysis, the relocation and installation costs would be approximately $30,250.

8.7 Site #7: West "O" St. (to 241+00)

The site-specific computer inputs for the computer model are as follows:

Roadway Width:	64 ft
Speed Limit:	40 mph
Roadway Cross-Section:	Two-Way, Four-Lanes, Curbed
Area Type:	Urban
Roadside Coverage Factor:	21.7%
Average Fixed Object Offset:	5.54 ft
Pole Offset (before):	7.52 ft
Pole Offset (after):	9.32 ft
Pole Configuration:	Both Sides
Number of Poles:	21 unobstructed (before) 20 unobstructed (after)
Pole Type:	Metal
Base Year ADT:	25,800
Traffic Growth:	3%
Actual Accident Experience:	0.36 accidents per year
Project Cost:	$26,800
Project Life:	20 years
Interest Rate	8%

The actual accident experience revealed that there were 0.36 accidents per year along the roadway section. The accident predictive model estimated that there would be approximately 0.60 accidents per year. Thus, the accident predictive model was assumed to be a conservative indicator of the accident experience after the project was to be implemented.

The first step of the analysis of Site #7 was to run the scenario which is to be implemented in the field, involving the relocation of the light poles from approximately 8 ft to 9 ft. The initial computer analysis also included runs varying the lateral offset from 9 ft to 18 ft in 1 ft increments. The computer analysis was performed for both the actual accident data and accident predictive model developed by Zegeer and Parker (32). It was evident that the predictive model would give conservative results.

The results of this analysis revealed the following:

Distance of Light Poles From Curb		Benefit-To-Cost Ratio	
		Accident Data	
Before	After	Actual	Predictive
8 ft	9 ft*	0.221*	0.369*
8 ft	10 ft	0.394	0.658
8 ft	11 ft	0.543	0.908
8 ft	12 ft	0.674	1.127
8 ft	13 ft	0.788	1.317
8 ft	14 ft	0.889	1.486
8 ft	15 ft	0.980	1.638
8 ft	16 ft	1.061	1.773
8 ft	17 ft	1.135	1.896
8 ft	18 ft	1.202	2.008

* - actual case calculated from proposed project plans

Benefit-to-cost ratios for the actual accident data indicate that it would have been cost-effective to relocate the luminaires to a 16 ft lateral offset from the curb, as shown in Figure 24. Although the current standards for lateral offset for this situation are a minimum of 6 ft from the curb, the actual field installation was located at an average lateral offset of 8 ft because of the presence of a sidewalk.

The computer analysis only evaluates lateral offset options which are 9 ft or greater; however, standards for the curbed "after" case situation required a minimum offset of only 6 ft from back of curb or behind the sidewalk, if applicable. Since the poles were already located 8 ft from the curb, it did not seem reasonable to run the computer model for a lateral offset alternative which was less than 8 ft (since such an alternative would produce a negative safety benefit).

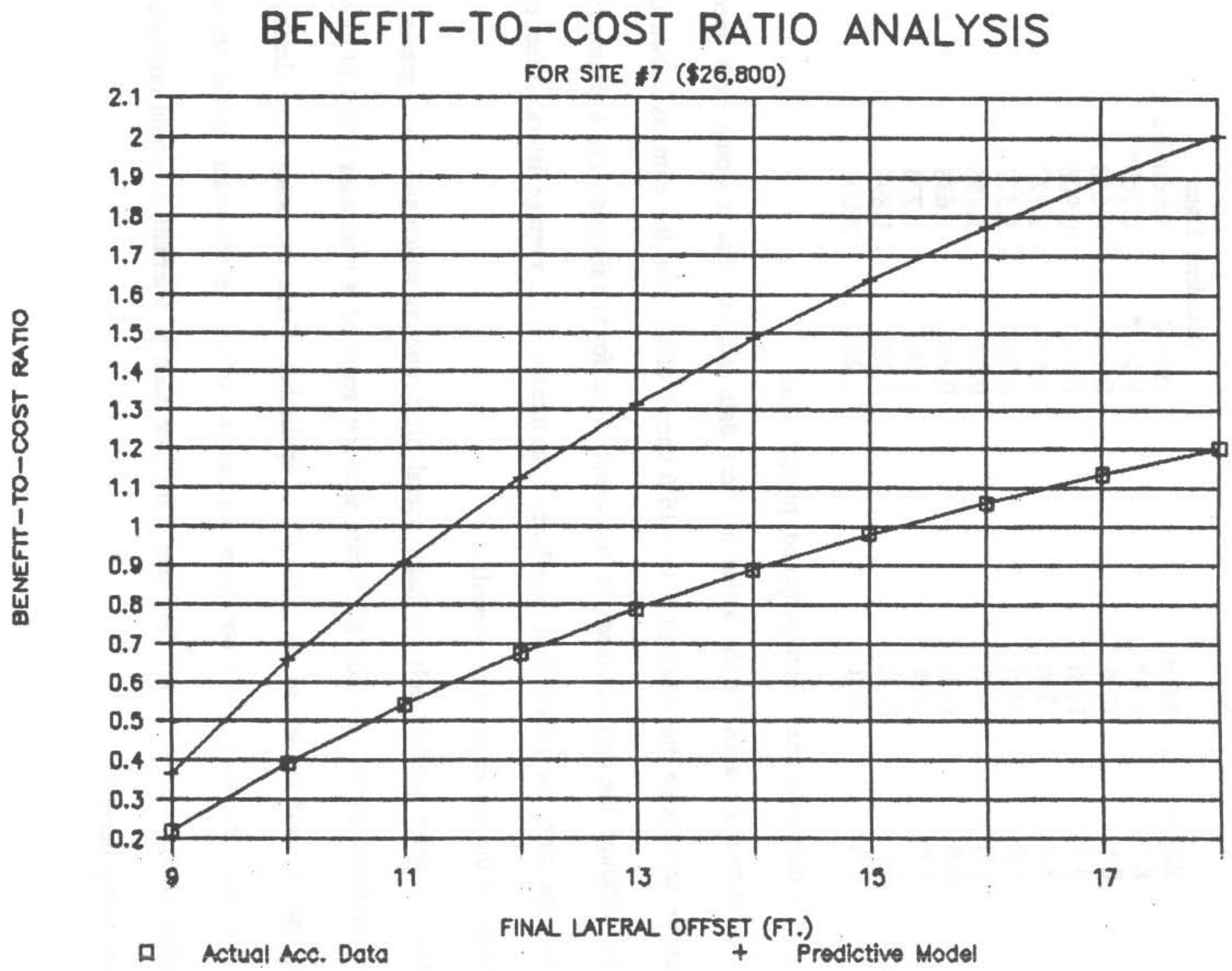


FIGURE 24. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR SITE #7 (26,800).

The benefit-to-cost ratios plotted in Figure 24 increased at a decreasing rate and began to level off at a final lateral offset of 14 ft and greater. However, the benefit-to-cost ratios do not level off as rapidly as the previous sites. One reason they do not may be the lower-than-average roadside coverage factor (the probability of striking a fixed object (obstacle) given that a vehicle runs a specified distance off the road).

Although the benefit-to-cost ratios were greater than 1.0 after a lateral offset of 16 ft, only a small number of accidents occurred during the "before" case situation. Consequently, it does not seem reasonable to relocate the light poles much farther than their present location. It should also be noted that the benefit-to-cost ratio analysis did not provide for the purchase of additional right-of-way which would further increase project costs.

The benefit-to-cost ratio analysis also considered the number of relocated luminaires which were able to be struck (unobstructed). The estimated relocation and installation costs of the light poles was determined from examining the original site survey plans to count the number of poles which were to be removed. The number and location of the new light poles was determined from our field visit after implementation of the project. Using the costs described in the Site #1 analysis, the relocation and installation costs would be approximately $26,800.

8.8 Summary and Conclusions of "UPACE"Site Analyses:

The results of the analyses performed for most of the seven field locations indicate that the current standards for curbed sections along new and reconstructed municipal state highways are satisfactory. The 6 ft minimum lateral obstacle clearance was adequate in most of the seven field sites; Sites #4, #6, and #7 are exceptions. The site-specific results are presented in Table 12.

TABLE 12.

Summary of "UPACE" Site-Specific Analyses

Field Location	Pole Offset		Lateral Obstacle State Standard (ft)	Minimum Req. Offset (ft)	Maximum Effect. Offset (ft)
	Initial (ft)	Final (ft)			
Site #1 ($625,882.62)	2	8	6	5	10^{+}
Site #1 ($103,000)	2	8	6	NA	10^{+}
Site #2 ($5,299.12)	2	10	6	NA	10
Site #2 ($12,850)	2	10	6	NA	10
Site #3 ($3,372.10)	3	10	6	5	10
Site #3 ($11,850)	3	10	6	6	10
Site #4 ($63,125)	3	8	6	7	12
Site #5 ($231,000) (underground)	3	9	6	NE	--
Site #5 ($42,000) (relocation only)	3	9	6	6	10
Site #6 ($30,250)	8	9	6	9	15
Site #7 ($26,800)	8	9	6	16	16

NA - Not Available (All of the offset distances produced benefit-to-cost ratios greater than 1.0)
NE - Non Existent (All of the offset distances produced benefit-to-cost ratios less than 1.0)

From the summary presented in Table 12, it is apparent that the 6 ft lateral obstacle offset standard was generally adequate while producing benefit-to-cost ratios of greater than 1.0 for most of the sites. If only minimal or no additional cost would arise from the acquisition of additional right-of-way, the data from these seven sites suggest that it would be advantageous to have a 10 ft minimum lateral obstacle clearance policy.

In many respects, five of the seven field locations were very similar. The various site specific values for the fixed-object coverage factor, fixed-object lateral offset, and the initial and final pole lateral offsets are shown in Table 13.

TABLE 13.

Summary of "UPACE" Site-Specific Field Conditions

Site No.	Coverage Factor	Fixed Object Lateral Offset (ft)	Initial Pole Lateral Offset (ft)	Final Pole Lateral Offset (ft)
1	60.5%	10.12	2.25	7.57
2	59.3%	9.39	2.44	9.67
3	58.0%	8.91	3.00	10.25
4	55.6%	11.53	3.39	8.25
5	63.0%	11.56	3.25	9.31
Average (1-5)	59.3%	10.30	2.87	9.01
6	17.5%	12.36	8.00	8.82
7	21.7%	5.54	7.52	9.32
Average (1-7)	47.9%	9.92	4.26	9.03

The average site-specific values, as shown in Table 13, were determined by using the data from sites 1 through 5 only. The reason for this is that some the site-specific data for sites 6 and 7 varied greatly from sites 1 through 5, as shown in Table 13. The average site-specific values were determined to be as follows:

Fixed Object Average Coverage Factor = 59.3%

Fixed Object Average Lateral Offset = 10.30 ft

Initial Pole Average Lateral Offset = 2.87 ft

Final Pole Average Lateral Offset = 9.01 ft

Using these average values for site-specific field data and the typical costs for relocations provided in Appendix K, recommended guidelines could be generated to aid in the evaluation of the current lateral obstacle clearance policies for a new or reconstructed municipal state highway, curbed section.

9 "UPACE" GENERAL SITE ANALYSES

9.1 Introduction

Based on the individual site analyses it was concluded that the 6 ft minimum lateral obstacle offset for a curbed, new or reconstructed Municipal State Highway was an effective and adequate minimum standard. This conclusion, however, was based on analysis of only three specific sites. The next step was to consider a typical site containing many of the average values obtained from the site analyses. These values were used for computer inputs and also to simplify the general site analysis. The average values for the following quantities were held as constants:

- Fixed Object Coverage Factor	=	60%
- Fixed Object Lateral Offset	=	9 ft
- Initial Pole Lateral Offset	=	2 ft

These values were selected because very little variance occurred between the three field locations.

Site-specific analyses had been performed only for the actual utility-installation type which had been or was planned to be implemented. As a result of those analyses, questions arose about the effect of various types of utility installations on the benefit-to-cost ratios. It was determined that the effect might be large if plans called for relocation of a larger utility line installation, since the relocation costs of utility installations increase significantly as the function of the utility line changes. Relocation costs provided by local utility companies confirmed this judgement (Appendix K).

9.2 Objective

Since the effects of the utility installation type were evident, the Civil Engineering Department, in consultation with the Nebraska Department of Roads, decided that the analysis should incorporate various typical utility installation types. A summary of these typical utility installation types is presented in Appendix K. The relocation cost information was obtained from two local utility companies and the street lighting division at the Nebraska Department of Roads (NDOR).

The objectives of the analyses were to identify which of the basic utility installation types would be cost-effective to implement, and, in addition, to determine an adequate minimum standard for lateral offset. The utility installation types were analyzed using the same general field scenario.

9.3 Scope

Seven different utility installation scenarios for the same general field location and roadway section were used for the general site analyses. The computer data inputs consisted of the following constant quantities:

- Section Length	=	2 mi. (10,560 ft)
- Urban Location		
- Four or Two Lane Roadway		
- Two-Way Traffic		
- Curbed Section		
- Speed Limit	=	40 mph
- Pole Configuration	=	one side
- Pole Type	=	see analyses
- Pole Spacing	=	see analyses
- Fixed Object Coverage Factor	=	0.60 (60%)
- Fixed Object Lateral Offset	=	9 ft
- Initial Pole Lateral Offset	=	2 ft
- Traffic Growth Rate	=	2%
- Fatal Accidents	=	1%

- Injury Accidents	=	46.3%
- PDO's	=	52.7%
- Cost/Fatality	=	$1,500,000
- Cost/Injury	=	$11,000
- Cost/PDO	=	$3,000
- Project Life	=	20 years
- Interest Rate	=	8%

The seven utility installation scenarios were as follows:

(1) Relocate Street Light Poles

(2) Modify Existing Street Light Poles to be Breakaway

(3) Relocate Local or Large Power Distribution Poles

(4) Modify Existing Local or Large Power Distribution Poles to be Breakaway

(5) Relocate Large (Heavy 3-phase) Power Distribution Poles

(6) Relocate Wood Power Transmission Poles

(7) Relocate Steel Power Transmission Poles

The results of the analysis are discussed in the following section.

9.3.1 Relocate Street Light Poles

Relocation of basic street lighting was the first utility installation type to be analyzed. Seventy-two metal, light poles were relocated from an initial offset of 2 ft to an undetermined final offset. The number of poles along the section was calculated using a typical 150 ft pole spacing. The light pole relocation cost was estimated $650/pole (Appendix K). The total project cost would be $46,800, resulting in an equivalent uniform annual cost (EUAC) of $4,767.

A benefit-to-cost ratio analysis was performed for the relocation of the light poles for a range of 3 ft to 12 ft in increments of 1 ft, and for the following ADT's: 500, 1250, 2500, 5000, 10000, 20000, 30000, and 40000. An example computer printout for the pole relocation analysis for 40000 ADT is provided in Appendix L. The results of the analysis are presented in Figure 25. It was evident that all of the relocation distances would be cost-effective since they all had benefit-to-cost ratios greater than 1.0. For ADT's as low as 500, the relocation of the poles would even be cost-effective. All of the benefit-to-cost ratios were much greater than 1.0; thus it was difficult to determine an adequate minimum lateral offset for relocating light poles.

The benefit-to-cost ratios reached their maximum point at approximately the 9 ft final lateral offset position, at which point the amount of benefit leveled off while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.

9.3.2 Modify Existing Street Light Poles to be Breakaway

Since the relocation of light poles was cost-effective in all aspects, the option for modifying the poles to be breakaway was analyzed. The analysis involved the conversion of 72 poles to breakaway poles at the original 2 ft lateral offset. Two different costs were used for converting metal light poles: $300/pole and $750/pole, for a total project cost of $21,600 and $54,000, respectively; and an equivalent uniform annual cost of $2,200 and $5,500, respectively. The cost of $300/pole was a more realistic cost figure, while the $750/pole cost could be used for situations in which high unexpected costs would be considered.

The analysis involved the use of the computer model at the following ADT's: 500, 1000, 2500, 5000, 10000, 20000, 30000, and 40000. An example computer printout for the breakaway analysis for an ADT of 500 is provided in Appendix L. The other significant variable was the percent reduction in severity for injury plus fatal accidents; 50% and 70%

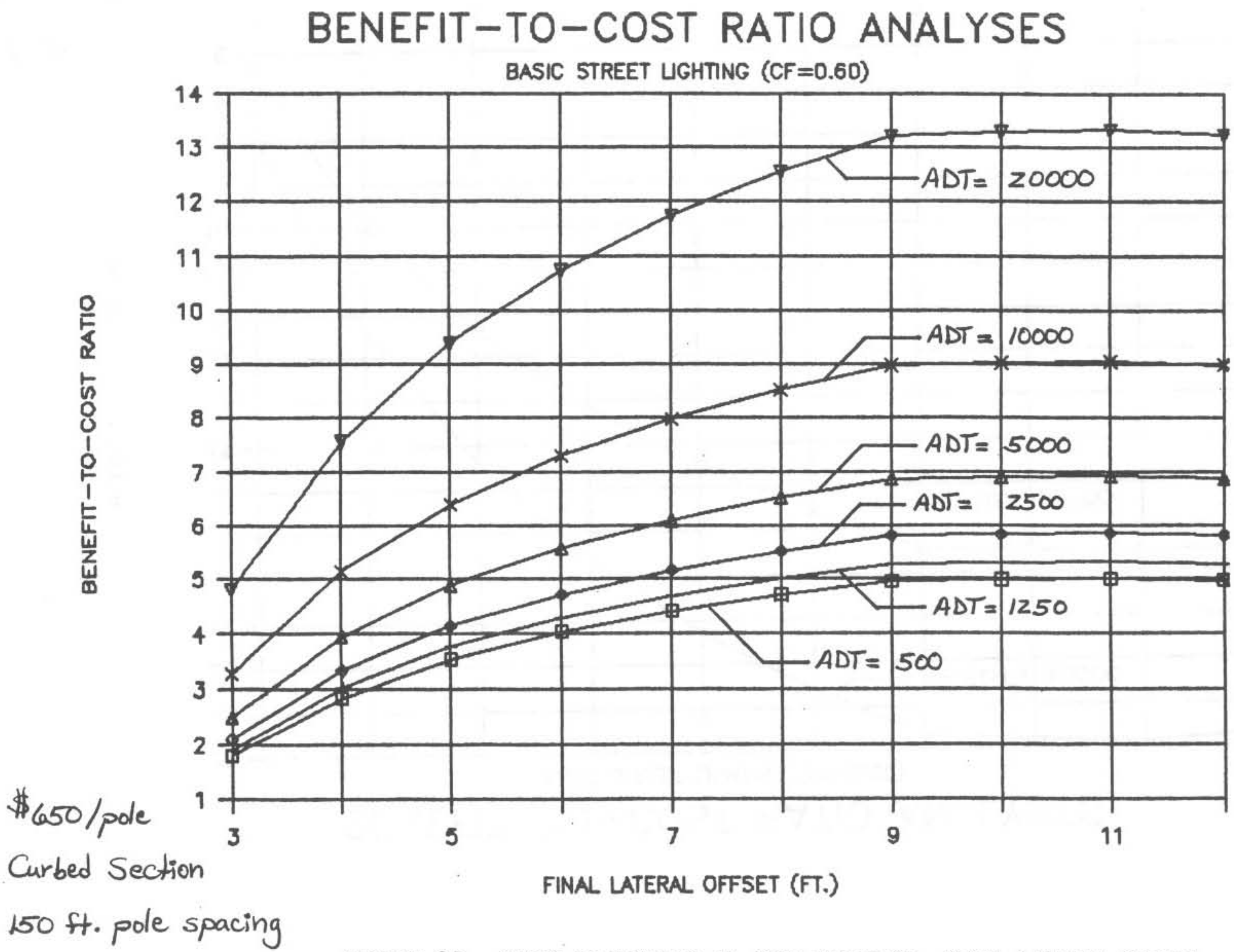
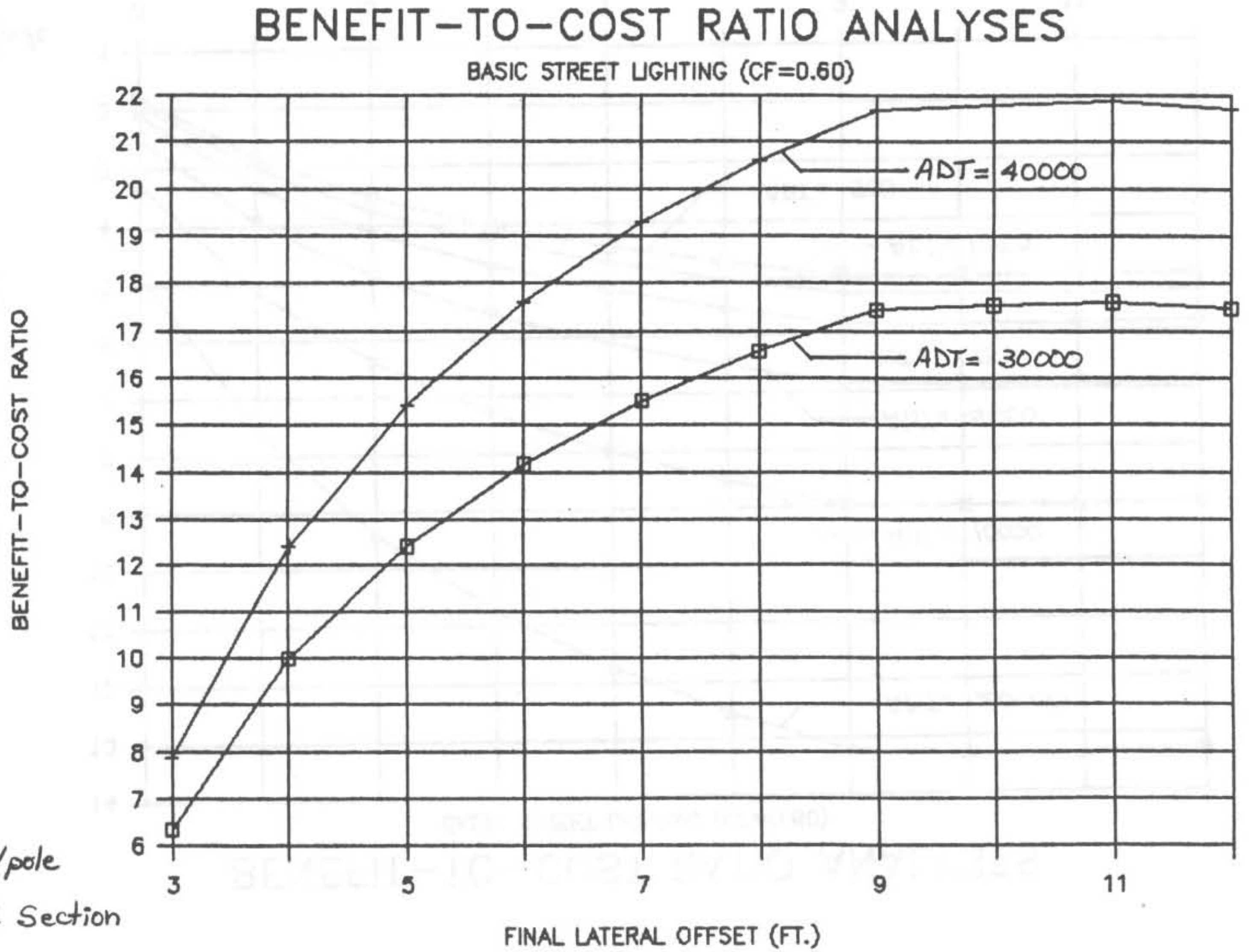


FIGURE 25. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR BASIC STREET LIGHTING.



#650 /pole
Curbed Section
150 ft. pole spacing

FIGURE 25C. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR BASIC STREET LIGHTING (CONT'D).

reductions in severity were considered. The results of the analysis are presented in Figure 26. It was evident that the breakaway light pole modification would be a cost-effective countermeasure at all of the given ADT's. Even when the higher cost and lower reduction in severity are considered, the breakaway light pole is shown to be a promising solution.

Both the relocation of light poles and the conversion to a breakaway system are shown to be cost-effective countermeasures, producing benefit-to-cost ratios greater than 1.0. Thus, it was appropriate to compare the two different types of installations.

9.3.3 Relocation Vs. Breakaway (Light Poles)

A comparison was performed for each of the relocation countermeasures and all of the breakaway countermeasures, for an ADT of 10,000.

ADT = 10000

Countermeasure	EUAC	EUAB	B/C
1. 2 ft to 3 ft	$4,767	$15,552	3.263
2. 2 ft to 4 ft	4,767	24,504	5.141
3. 2 ft to 5 ft	4,757	30,458	6.390
4. 2 ft to 6 ft	4,757	34,765	7.293
5. 2 ft to 7 ft	4,757	38,056	7.984
6. 2 ft to 8 ft	4,757	40,671	8.532
7. 2 ft to 9 ft	4,757	42,809	8.981
8. 2 ft to 10 ft	4,757	43,055	9.032
9. 2 ft to 11 ft	4,757	43,182	9.059
10. 2 ft to 12 ft	4,757	42,878	8.995
11. $750/pole, 50% reduc.	5,500	33,403	6.073
12. $750/pole, 70% reduc.	5,500	46,765	8.503
13. $300/pole, 50% reduc.	2,200	33,403	15.183
14. $300/pole, 70% reduc.	2,200	46,765	21.257

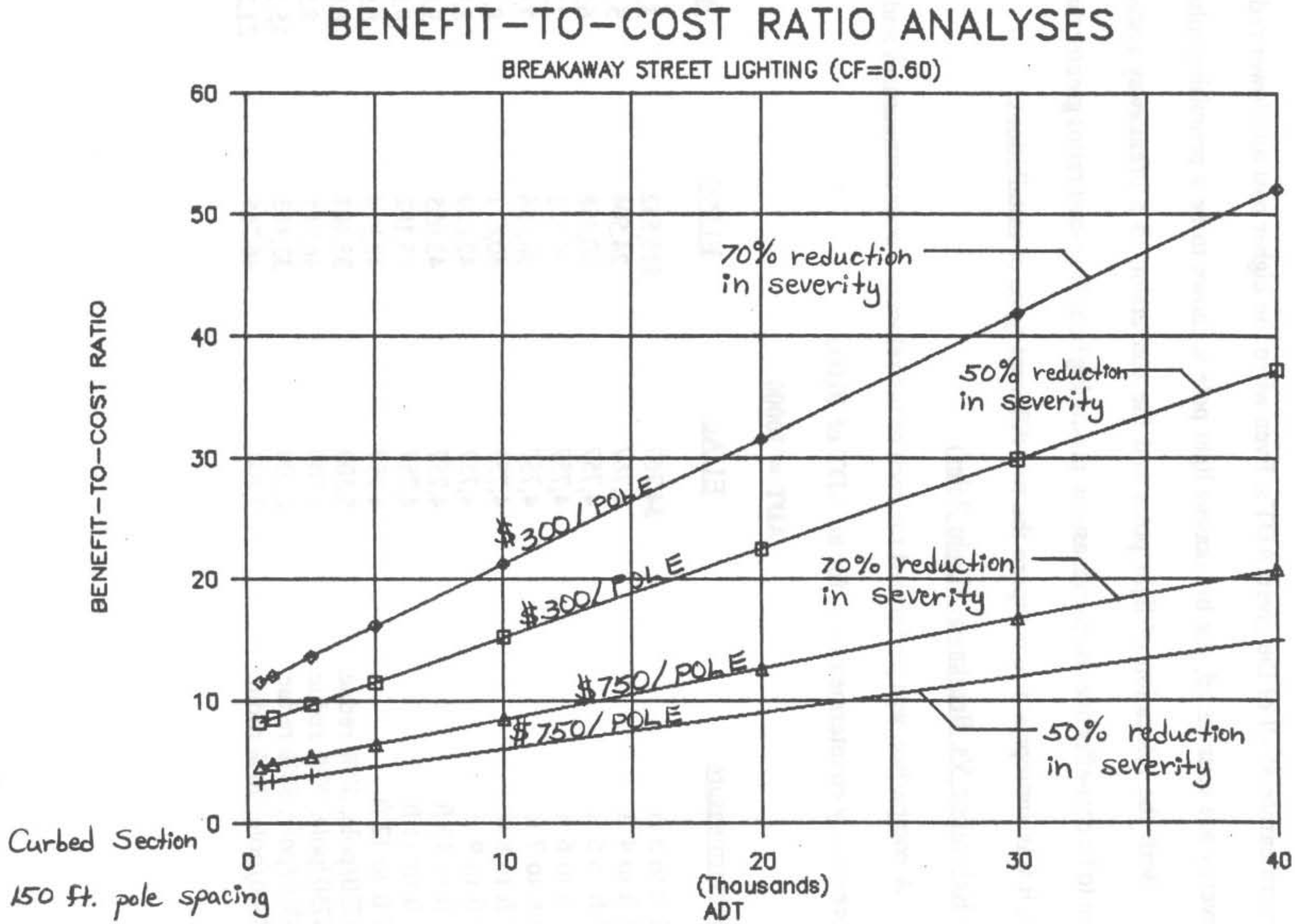


FIGURE 26. GRAPH OF BENEFIT-TO-COST RATIO VS. ADT FOR BREAKAWAY STREET LIGHTING.

An incremental benefit-to-cost ratio analysis showed that the least cost-effective breakaway countermeasure ($750/pole, 50% reduction) would be more cost-effective only for pole relocations up to 5 ft; while pole relocation would be more cost-effective for relocations of 6 ft or more.

Comparison of the breakaway countermeasure of $300/pole and 50% reduction with pole relocation showed that the breakaway poles would be more cost-effective for distances up to 6 ft; pole relocation would be more cost-effective for distances of 7 ft or more. The remaining two breakaway countermeasures, considering a 70% reduction, would provide the greatest benefit over pole relocations from an incremental benefit-to-cost ratio perspective.

9.3.4 Relocate Local or Large Power Distribution Poles

The analysis involved the relocation of 107 wood utility poles from an initial offset of 2 ft to an undetermined final offset. The number of poles along the section was calculated using a typical 100 ft pole spacing. The utility pole relocation cost was estimated to be $1,700/pole, as shown in Appendix K. The total project cost would be $181,900 resulting in an equivalent uniform annual cost of $18,527.

A benefit-to-cost ratio analysis was performed for the relocation of the utility poles for a range of 3 ft to 12 ft in increments of 1 ft, and for the following ADT's: 500, 5000, 10000, 20000, 30000, and 40000. The results of the analysis are presented in Figure 27. For ADT's greater than 500, it was evident that it would be cost-effective to relocate the utility poles to a final lateral offset of 4 ft or greater.

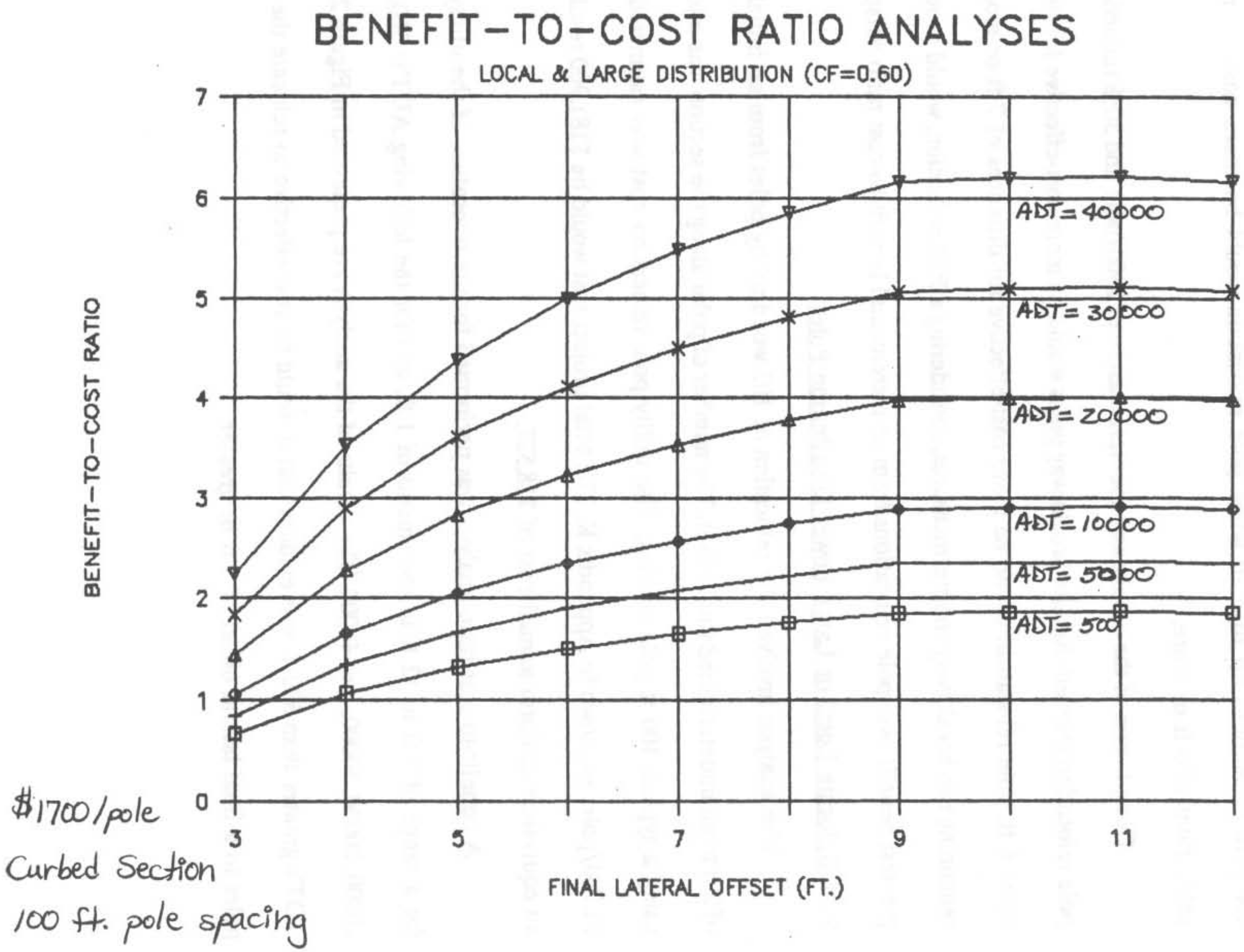


FIGURE 27. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR LOCAL OR LARGE POWER DISTRIBUTION.

The benefit-to-cost ratios reached their maximum at approximately the 9 ft final lateral offset position; benefit leveled off at this point while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.

9.3.5 Modify Existing Local and Large Power Distribution Poles to be Breakaway

The countermeasure for modifying the local or large power distribution poles was analyzed. The analysis involved the conversion of 107 poles to breakaway poles at the original 2 ft lateral offset. The implementation cost per pole was $2,675 for a total project cost of $286,225, and resulting in an equivalent uniform annual cost of $29,158.

A benefit-to-cost ratio analysis was performed for the modification of the existing poles to be breakaway. The analysis involved the use of the computer model at the following ADT's: 500, 5000, 10000, 20000, 30000, and 40000.

The other significant variable was the percent reduction in severity for injury plus fatal accidents; 70% and 90% reductions in severity were used. Zegeer, Cynecki, and Parker had suggested values between 30% and 60% (18,32); later, Ivey and Morgan reported values between 91% and 97% (43). The 70% and 90% reduction values were selected.

The analysis indicated that the breakaway utility pole modification would be a cost-effective countermeasure at all of the given ADT's (Figure 28). Even for the lower reduction in severity, the breakaway utility pole are shown to be a promising solution. Both the relocation of the local or large distribution utility poles and the conversion to a breakaway system are cost-effective. Both modifications produced benefit-to-cost ratios greater than 1.0. Thus, it was appropriate to compare the two different types of installations.

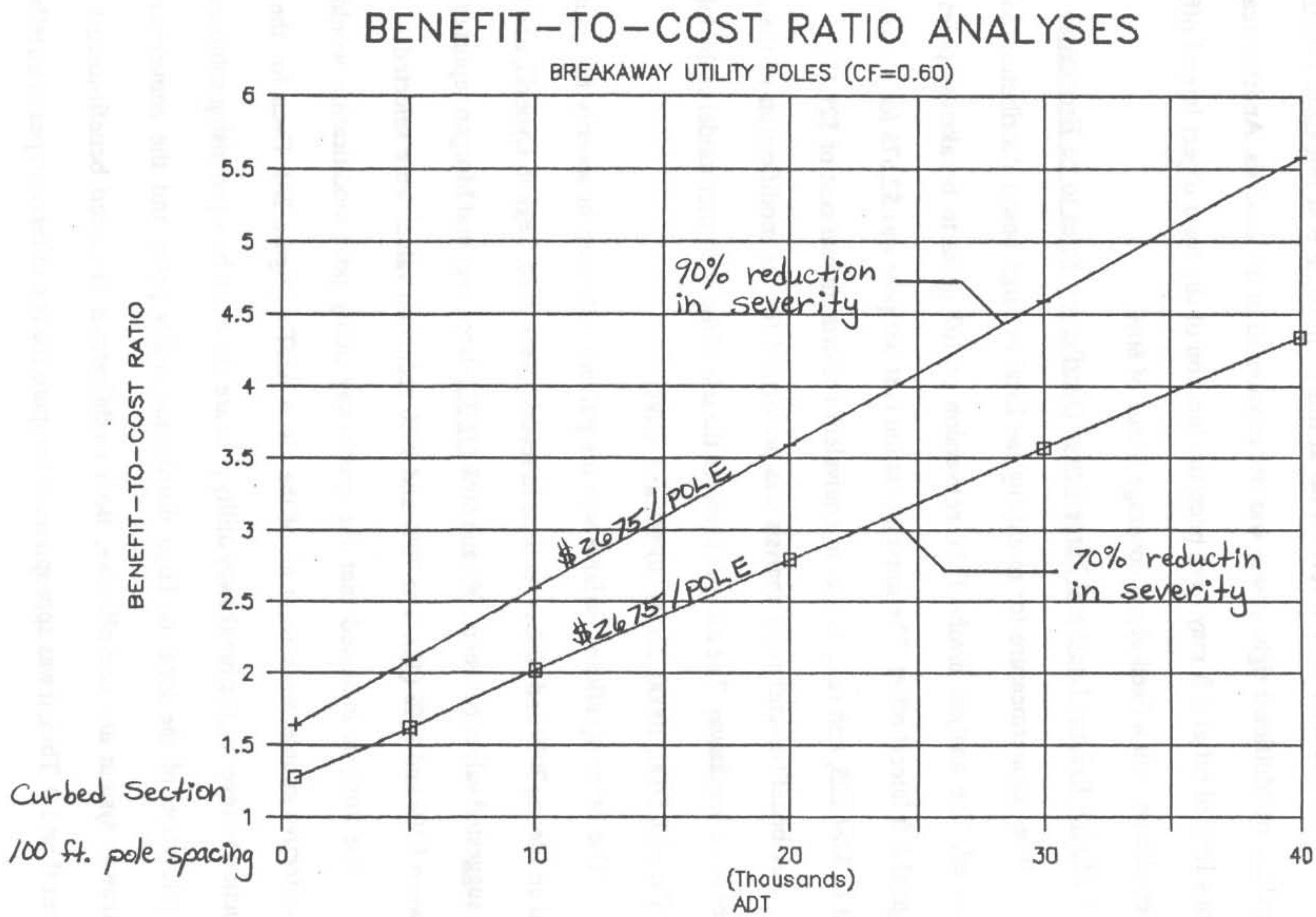


FIGURE 28. GRAPH OF BENEFIT-TO-COST RATIO VS. ADT FOR BREAKAWAY UTILITY POLES.

9.3.6 Relocation Vs. Breakaway (Utility Poles)

A comparison was performed for each of the relocation countermeasures and all of the breakaway countermeasures, at an ADT of 10000.

ADT = 10000

Countermeasure	EUAC	EUAB	B/C
1. 2 ft to 3 ft	$18,527	$19,432	1.049
2. 2 ft to 4 ft	18,527	30,617	1.653
3. 2 ft to 5 ft	18,527	38,057	2.054
4. 2 ft to 6 ft	18,527	43,438	2.345
5. 2 ft to 7 ft	18,527	47,550	2.567
6. 2 ft to 8 ft	18,527	50,817	2.743
7. 2 ft to 9 ft	18,527	53,489	2.887
8. 2 ft to 10 ft	18,527	53,796	2.904
9. 2 ft to 11 ft	18,527	53,954	2.912
10. 2 ft to 12 ft	18,527	53,575	2.892
11. $2,675/pole, 70% reduc.	29,153	58,743	2.015
12. $2,675/pole, 90% reduc.	29,153	75,506	2.590

An incremental benefit-to-cost ratio analysis showed that the least cost-effective breakaway countermeasure (70% reduction) would be more cost-effective than pole relocations only up to 7 ft, while pole relocation would be more cost-effective for relocations of 8 ft or more. The breakaway countermeasure of a 90% reduction in severity was found to be more cost-effective than any of the pole relocations considered.

9.3.7 Relocate Large (Heavy 3-phase) Power Distribution Poles

The analysis involved the relocation of 107 wood utility poles from an initial offset of 2 ft to an undetermined final offset. The number of poles along the section was calculated using a typical pole spacing distance of 100 ft. The utility pole relocation cost was $3,500/pole, as shown in Appendix K. The total project cost was $374,500 resulting in an equivalent uniform annual cost of $38,144.

A benefit-to-cost ratio analysis was performed for the relocation of the utility poles for the range of 3 ft to 12 ft in increments of 1 ft, and for the following ADT's: 5000, 10000, 20000, 30000, and 40000. The results of the analysis are presented in Figure 29. For ADT's greater than 5000, it was evident that it would be cost-effective to relocate the utility poles to a final lateral offset of 7 ft or greater. However, if a larger ADT was present, then, it would be cost-effective to relocate the utility poles to a lateral offset of 5 ft to 6 ft.

The benefit-to-cost ratios reached their maximum point at approximately the 9 ft final lateral offset position; at this point the amount of benefit leveled off while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.

9.3.8 <u>Relocate Wood Power Transmission Poles</u>

The analysis involved the relocation of 37 wood utility poles from an initial offset of 2 ft to an undetermined final offset. The number of poles along the section was calculated using a typical 300 ft pole spacing. The utility pole relocation cost was $8,350/pole (Appendix K). The total project cost was $308,950, for an EUAC of $31,467.

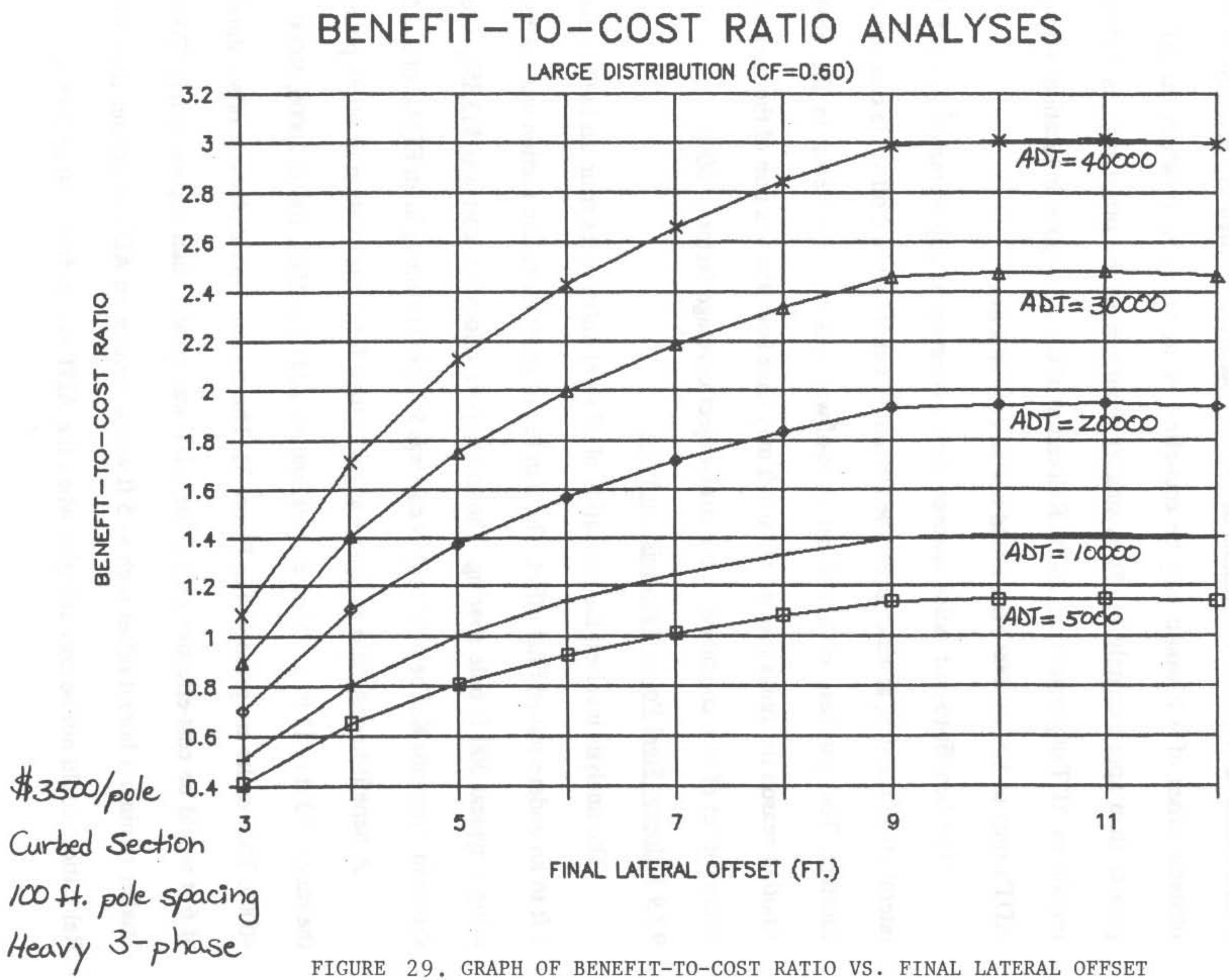


FIGURE 29. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR LARGE DISTRIBUTION.

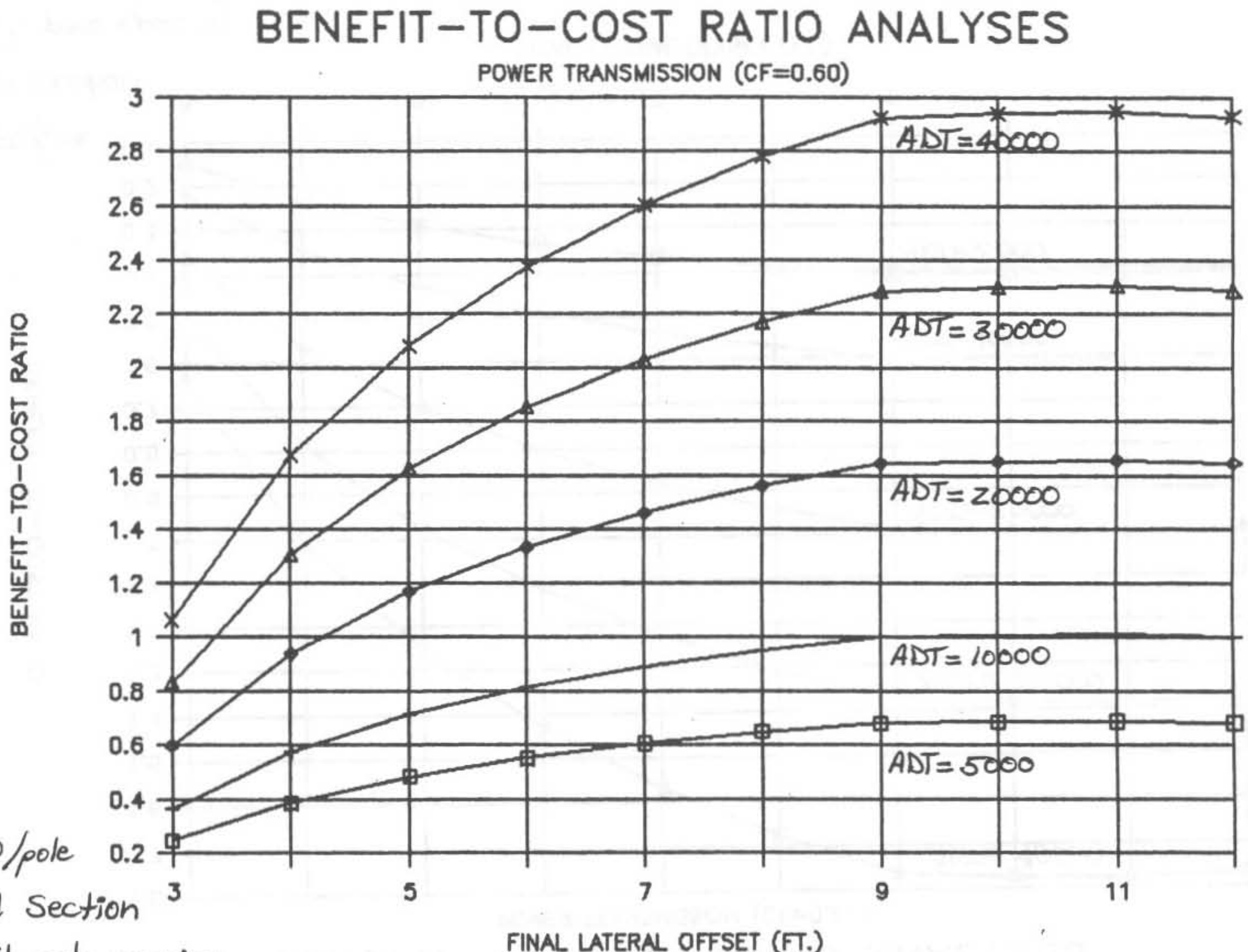
The benefit-to-cost ratio analysis was performed for the relocation of the utility poles for the range of 3 ft to 12 ft in increments of 1 ft, and for the following ADT's: 5000, 10000, 20000, 30000, and 40000. The results of the analysis are presented in Figure 30. A lateral obstacle offset of 6 ft would only be cost-effective in situations in which the ADT was greater than approximately 14000. A smaller minimum lateral offset such as 5 ft would require an ADT of greater than 20000. Relocation of the utility poles in locations where low ADT's such as 500 to 5000 exist would not be cost-effective.

The benefit-to-cost ratios reached their maximum at approximately the 9 ft final lateral offset position, at which point the amount of benefit leveled off while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.

9.3.9 Relocate Steel Power Transmission Poles

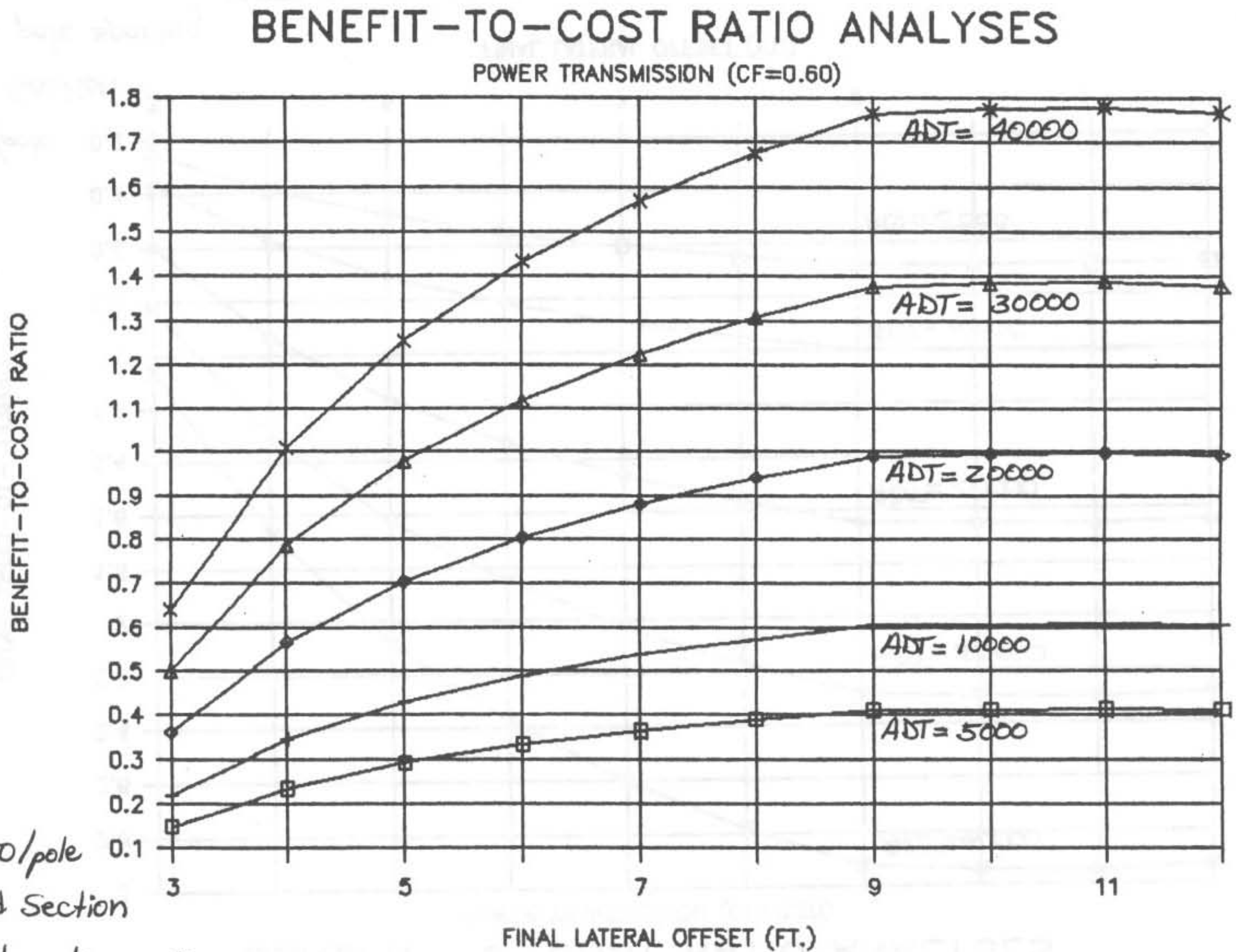
The analysis involved the relocation of 37 steel utility poles from an initial offset of 2 ft to an undetermined final offset. The number of poles along the section was calculated using a typical 300 ft pole spacing. The utility pole relocation cost was $13,850/pole, as shown in Appendix K. The total project cost was $512,450 resulting in an EUAC of $52,193.

A benefit-to-cost ratio analysis was performed for the relocation of utility poles for the range of 3 ft to 12 ft in 1 ft increments, and for ADT's of 5000, 10000, 20000, 30000, and 40000. The results are presented in Figure 31. The current lateral obstacle offset standard of 6 ft would be cost-effective only if the ADT was greater than approximately 27000. A smaller minimum lateral offset such as 5 ft would require an ADT of greater than 30000. Relocation would not be cost-effective when the ADT ranges from 500 to 20000.



$8350/pole
Curbed Section
300 ft. pole spacing
Wood Poles

FIGURE 30. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR POWER TRANSMISSION (WOOD POLES).



$13850/pole
Curbed Section
300 ft. pole spacing
Steel Poles

FIGURE 31. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR POWER TRANSMISSION (STEEL POLES).

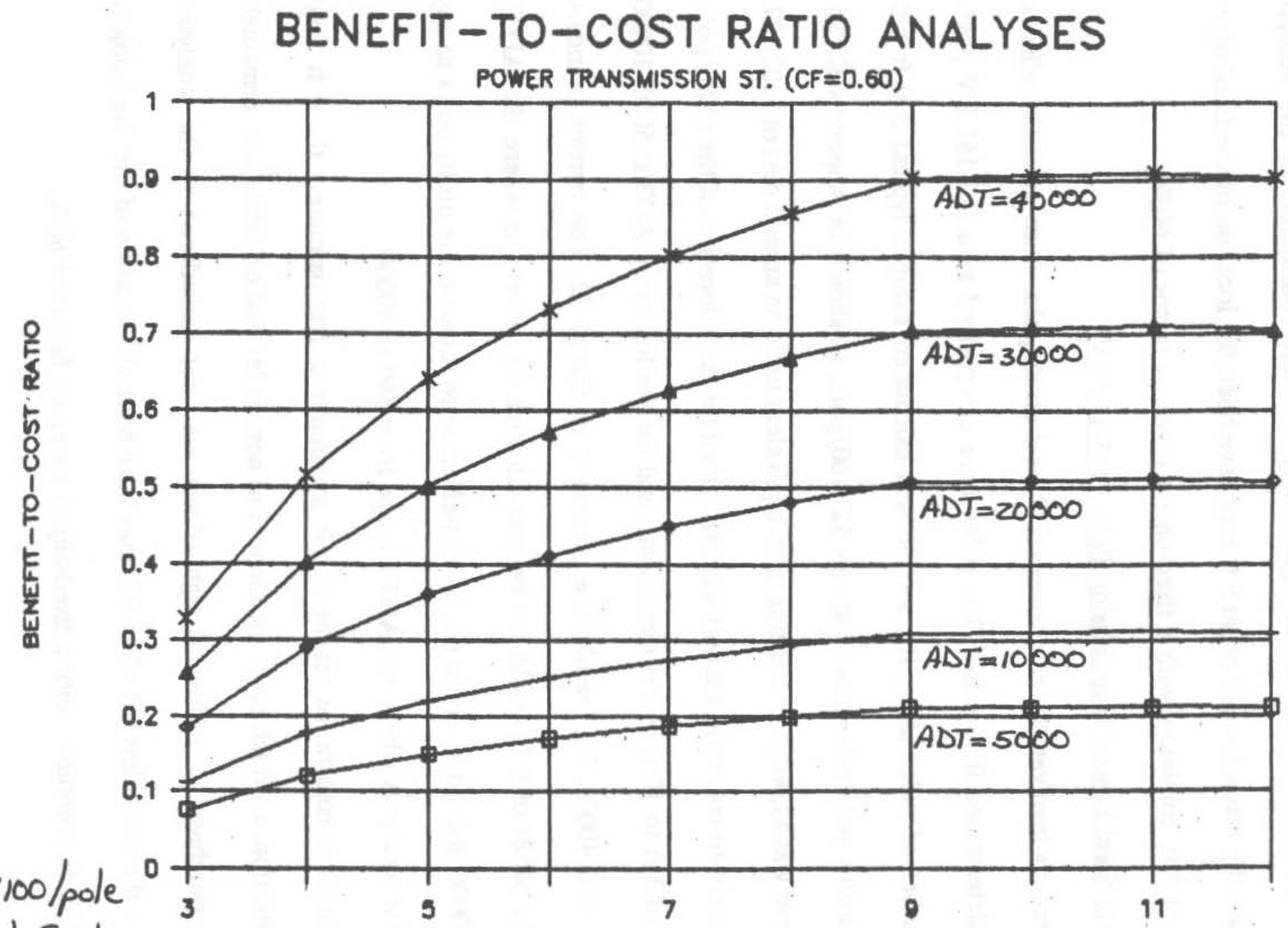
The benefit-to-cost ratios reached their maximum at approximately the 9 ft final lateral offset position, at which point the amount of benefit leveled off while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.

9.3.10 Relocate Steel Power Transmission Poles (115-161 KV)

The analysis involved the relocation of 37 steel utility poles from an initial offset of 2 ft to an undetermined final offset. The poles were categorized as a 115-161 KV power line. The number of poles along the section was calculated using a typical 300 ft pole spacing. The utility pole relocation cost was $27,100/pole, as shown in Appendix K. The total project cost was $1,002,700 resulting in an equivalent uniform annual cost of $102,127.

The benefit-to-cost ratio analysis was performed for the relocation of the utility poles for the range of 3 ft to 12 ft in 1 ft increments, and for the following ADT's: 5000, 10000, 20000, 30000, and 40000. The results are presented in Figure 32. The current standard lateral obstacle offset of 6 ft would not be cost-effective for situations where the ADT's varied up to 40000; indeed, it would not be cost-effective to relocate the utility poles to any lateral offset for locations where the ADT's range from 500 to 40000.

The benefit-to-cost ratios reached their maximum at approximately the 9 ft final lateral offset position, at which point the amount of benefit leveled off while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.



#27100/pole
Curbed Section
300 ft. pole spacing
Steel Poles (115-161 KV)

FIGURE 32. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR STEEL POWER TRANSMISSION POLES (115-161 KV).

9.3.11 Relocate Wood Power Transmission and Distribution Poles

The analysis involved the relocation of 37 wood utility poles from an initial offset of 2 ft to an undetermined final offset. The number of poles along the section was calculated using a typical 300 ft pole spacing. The utility pole relocation cost was $15,850/pole, as shown in Appendix K. The total project cost was $586,450 resulting in an equivalent uniform annual cost of $59,731.

A benefit-to-cost ratio analysis was performed for the relocation of the utility poles for the range of 3 ft to 12 ft in 1 ft increments, and for the following ADT's: 5000, 10000, 20000, 30000, and 40000. The results of the analysis are presented in Figure 33. The current standard lateral obstacle offset of 6 ft would only be cost-effective in situations where the ADT was greater than approximately 30000; an ADT of greater than 36,000 would be required in order for a smaller minimum lateral offset, such as 5 ft, to be used. For locations where the ADT ranges from 500 to 24000, it would not be cost-effective to relocate the utility poles.

The benefit-to-cost ratios reached their maximum at approximately the 9 ft final lateral offset position, at which point the amount of benefit leveled off while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.

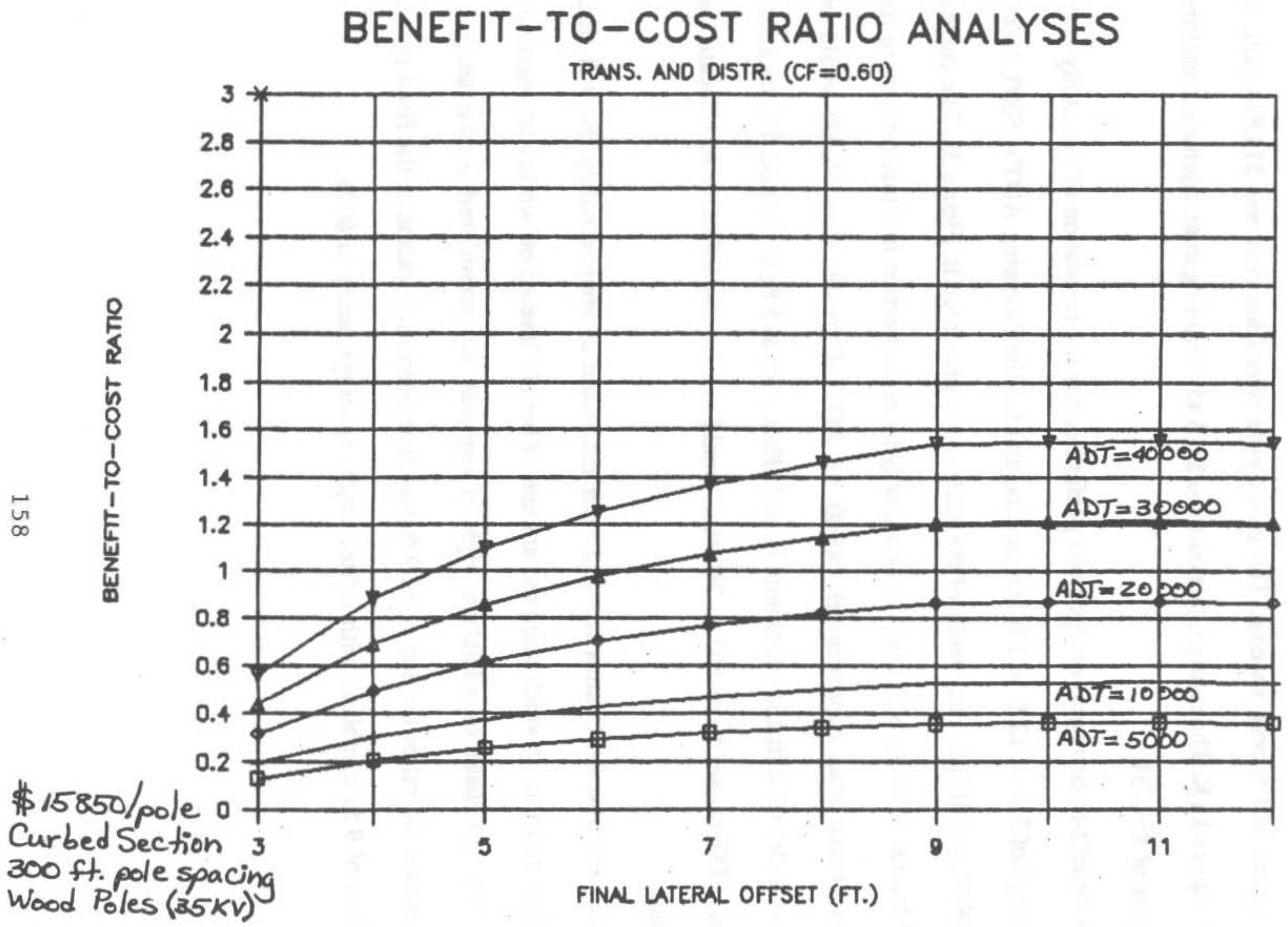


FIGURE 33. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR POWER TRANSMISSION AND DISTRIBUTION POLES(WOOD POLES).

9.3.12 Relocate Steel Power Transmission and Distribution Poles

The analysis involved the relocation of 37 steel utility poles from an initial offset of 2 ft to an undetermined final offset. The number of poles along the section was calculated using a typical spacing distance of 300 ft. The utility pole relocation cost was $30,600/pole, as shown in Appendix K. The total project cost was $1,132,000 resulting in an equivalent uniform annual cost of $115,297.

A benefit-to-cost ratio analysis was performed for the relocation of the utility poles for the range of 3 ft to 12 ft in 1 ft increments, and for the following ADT's: 5000, 10000, 20000, 30000, and 40000. The results of the analysis are presented in Figure 34. The current standard lateral obstacle offset of 6 ft would not be cost-effective for situations where the ADT's varied up to 40000; in locations where the ADT's range from 500 to 40000, it would not be cost effective to relocate the utility poles to any lateral offset.

The benefit-to-cost ratios reached their maximum at approximately the 9 ft final lateral offset position, at which point the amount of benefit leveled off while cost remained constant. The purchase of additional right-of-way was not considered in the analysis. Another reason the ratios leveled off at 9 ft may have been the location of the fixed object lateral offset of 9 ft, combined with a fixed-object coverage factor of 60%.

9.4 Summary and Conclusions for General Site Analyses

The analyses of the utility installations may be summarized as follows:

(1) Relocation of Street Lighting:

- Relocation of poles to any final lateral-offset for ADT's between 500 to 40000 would be cost-effective; however,

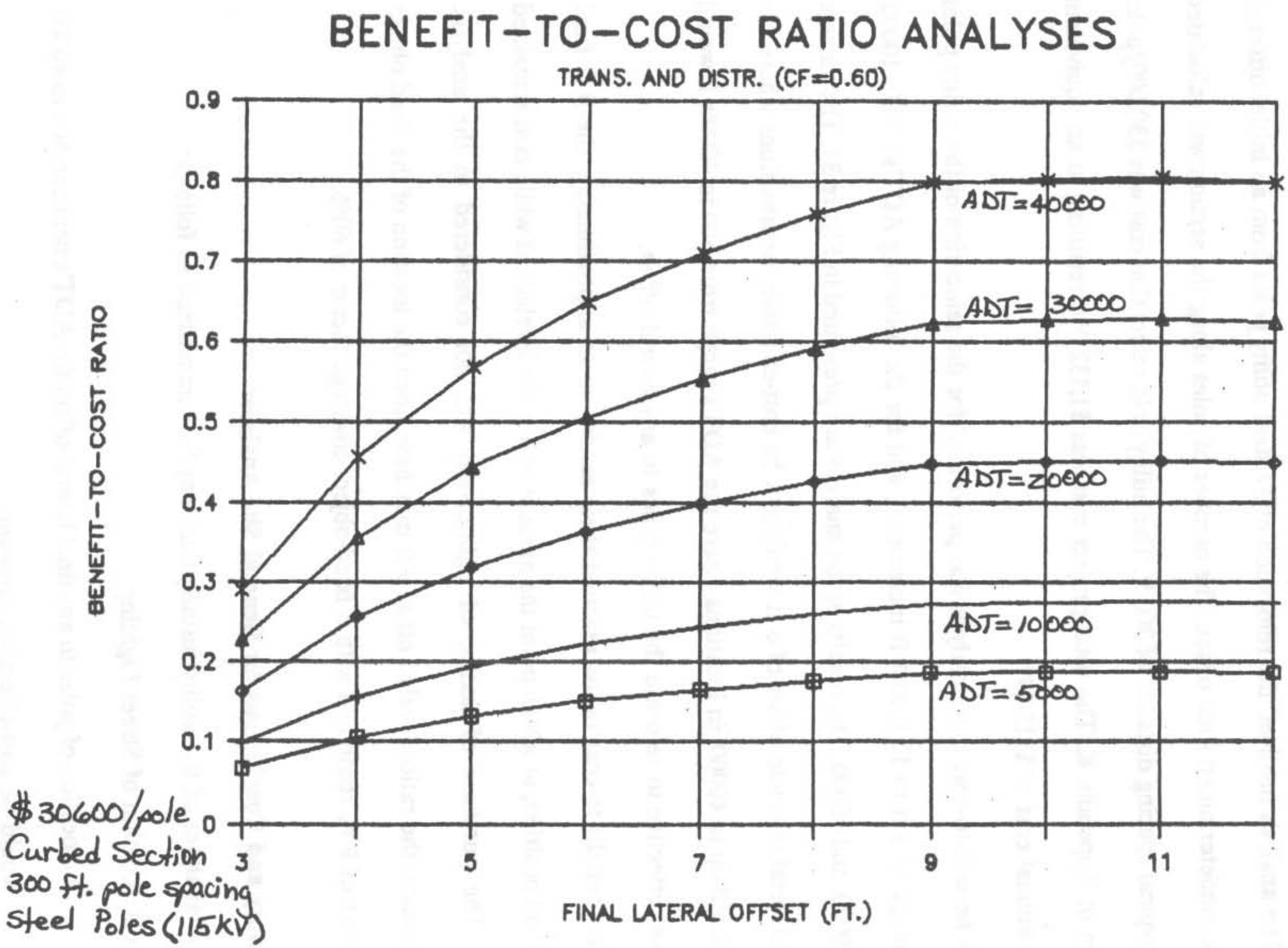


FIGURE 34. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR POWER TRANSMISSION AND DISTRIBUTION POLES (STEEL POLES).

- there would be no increase in benefit beyond the 9 ft lateral-offset position.

(2) Breakaway Street Lighting:

- Conversion of the existing light poles to be breakaway would be cost-effective; indeed,
- even with high installation costs and a lower reduction in severity, the breakaway light pole was shown to be cost-effective.

(3) Relocation versus Breakaway (Light Poles):

- For the 50% reduction in severity cases, breakaway poles were more cost-effective than pole relocations up to approximately 6 ft; likewise,
- for the 70% reduction in severity cases, breakaway poles were more cost-effective than pole relocations for all the lateral-offsets analyzed.

(4) Relocation of Local or Large Distribution:

- Relocation of poles to a final lateral-offset of 4 ft or greater for ADT's between 500 to 40000 would be cost-effective; however,
- there would be no increase in benefit beyond the 9 ft lateral-offset position.

(5) Breakaway Local or Large Distribution:

- Conversion of the existing utility poles to be breakaway would be cost-effective; indeed,
- even with a lower reduction in severity, the breakaway utility pole was shown to be cost-effective.

(6) Relocation Vs. Breakaway (Utility Poles):

- For the 70% reduction in severity cases, breakaway poles were more cost-effective than pole relocations up to 7 ft; similarly,

- for the 90% reduction in severity cases, breakaway poles were more cost-effective than all the pole relocations analyzed.

(7) Relocation of Large (Heavy 3-phase) Distribution:

- Relocation of poles to a final lateral offset of 7 ft or greater would be cost-effective for ADT's greater than 5000;
- for larger ADT's, such as 15000 to 40000, it would be cost-effective to relocate poles to a minimum final lateral offset of 5 ft to 6 ft; however,
- there would be no increase in benefit beyond the 9 ft lateral-offset position.

(8) Relocation of Wood Transmission Poles:

- At the current standard of the 6 ft minimum lateral offset, an ADT of 14000 or greater would be required for a cost-effective relocation;
- for ADT's less than 10000, it would not be cost-effective to relocate the utility poles; likewise,
- there would be no increase in benefit beyond the 9 ft lateral-offset position.

(9) Relocation of Steel Transmission Poles:

- At the current standard of the 6 ft minimum lateral offset, an ADT of 27000 or greater would be required for a cost-effective relocation;
- for ADT's less than 20000, it would not be cost-effective to relocate the utility poles; and similarly,
- there would be no increase in benefit after the 9 ft lateral-offset position.

(10) Relocation of Large Steel Transmission Poles:

- At the current standard of the 6 ft minimum lateral offset, pole relocations would not be cost-effective where the ADT's ranged from 500 to 40000;

- likewise, there would be no increase in benefit after the 9 ft lateral-offset position.

(11) Relocation of Wood Power Transmission Poles Plus Distribution Underbuilt

- At the current standard of the 6 ft minimum lateral offset, an ADT of 30000 or greater would be required for a cost-effective relocation;
- for ADT's less than 24000, it would not be cost-effective to relocate the utility poles; and similarly,
- there would be no increase in benefit after the 9 ft lateral-offset position.

(12) Relocation of Steel Power Transmission Poles Plus Distribution Underbuilt

- At the current standard of the 6 ft minimum lateral offset, it would not be cost-effective for pole relocations where the ADT's ranged from 500 to 40000;
- there would be no increase in benefit after the 9 ft lateral-offset position.

It should be noted that the "UPACE" general site analyses were performed for various typical installation types. Many of the major computer inputs were based upon field investigations for the site specific analyses. These inputs were used because they were found to be representative of the selected sites for urban areas in Nebraska.

The conclusions for both the specific site and the general analyses may be used as a guide for determining whether a utility or light pole countermeasure for a curbed section along a new or reconstructed municipal state highway should be imple-mented. However, these conclusions cannot replace actual field observation. If a project is a serious candidate for implementation, field visits are recommended to obtain data and necessary computer inputs since variables such as the fixed object lateral offset and fixed object coverage factor can significantly affect the results.

However, there would be no increase in benefits since the 9 ft lateral offset persists.

(2) Relocation of Wood Power Transmission Pole with Distribution Underbuilt

(a) At the current [illegible] of the 9 ft [illegible] lateral offset, an ADT of 30000 or greater would be required for a cost-effective relocation;

(b) If the ADT is less than 24000, it would not be cost-effective to relocate the poles [illegible].

There would be no increase in benefits since the 9 ft lateral offset persists.

(3) Relocation of Wood Power Transmission Poles with Distribution Underbuilt

(a) At the current [illegible] of these 9 ft lateral offset poles, it would not be cost-effective [illegible] when [illegible] ADT [illegible];

(b) There would be no increase in benefits since the 9 ft lateral offset persists.

It should be noted that the [illegible] generated cost analyses were performed for a single typical installation [illegible] and the major computer inputs were based upon field investigations for the [illegible] analyses. These inputs were used because they were found to be representative of the selected sites [illegible] areas in Nebraska.

The [illegible] the specific site and the general analyses [illegible] a guide for determining whether a utility or light pole [illegible] section [illegible] should be [illegible]. However, [illegible] is a serious [illegible] data [illegible] input [illegible] variables such as the [illegible] and [illegible] significantly [illegible].

10 "ROADSIDE" METHODOLOGY

10.1 Introduction

In order to assist highway design engineers in evaluating the cost of a proposed roadside improvement versus the expected benefit, an update to the 1977 AASHTO Barrier Guide Methodology was developed and presented in the AASHTO Roadside Design Guide (19). This update was a computer program called "ROADSIDE"; the program has been written in Quick Basic 4 and can be used by IBM and IBM-compatible personal computers.

The computer program permits the designer to approximate the total annualized costs of alternative measures. These total costs include initial construction, repair and maintenance costs, salvage value, and user costs. "Roadside" relates the number of accidents to the number of predicted encroachments and the probabilities of these encroachments resulting in an impact with the described hazard.

Unlike the "Barrier Guide" Methodology, the "ROADSIDE" model includes the effects of roadway grade and curvature, including the effects of opposite-direction encroachments on undivided two-way roadways. The model also relates the lateral extent of encroachment as well as accident severity to the design speed of the roadway. Finally, the model calculates the traffic growth over the given project life and incorporates this factor into the economic analysis.

10.2 Computer Method

Although the calculations can be made manually, the computer program is much more efficient. Program output (i.e., annualized costs) can be manipulated by the design engineer in order to predict the total costs associated with specific traffic and roadway conditions. The design engineer can then select the most appropriate design from among the alternative options.

10.3 Data Requirements

The following sets of variables used in the computer model for conducting the cost-effectiveness analysis are as follows:

(1) Basic Input Data

(2) Specific Roadway and Roadside Characteristics

(3) Global Values

10.4 Basic Input Data

10.4.1 Traffic Volume

The design year traffic (ADT_{dy}) is a function of the initial traffic volume (ADT_o), estimated traffic growth rate (TGR), and the assigned project life (PL). The relationship is shown below:

$$ADT_{dy} = ADT_o \left[1 + \frac{TGR}{100}\right]^{PL}$$

where ADT_o, TGR, and PL are input variables and ADT_{dy} is a computed value. For two-way divided and undivided roadways, the traffic volume is assumed to be equally distributed between adjacent and opposing traffic.

10.4.2 Project Life and Discount Rate

The project life (PL) defines the useful life of the project; it is also the period of time over which the cost-effective analysis is performed. The discount rate is used to calculate the economic factors used to determine present worth and annual costs.

10.4.3 Highway Agency Costs

Highway agency costs consist of installation costs, maintenance and repair costs, and salvage value:

Installation Costs

The installation cost is the total cost to the highway agency of installing a safety feature or modifying or removing an existing hazard. The installation cost for the original or do-nothing case would be zero.

Maintenance Costs

The annual cost of maintaining either an existing condition or an appurtenance proposed for installation.

Repair Costs

The estimated cost to repair or replace an appurtenance which is damaged as a result of an accident.

Salvage Value

The estimated value of the materials used for the project at the end of the project life. In most cases the value is negligible.

10.5 Specific Roadway and Roadside Characteristics

10.5.1 Roadway Type

The program addresses three types of highways: divided, undivided, and one-way. On a two-way undivided roadway, encroachments by both adjacent and opposite-direction traffic are calculated. Figure 35 illustrates the encroachments by roadway type (19).

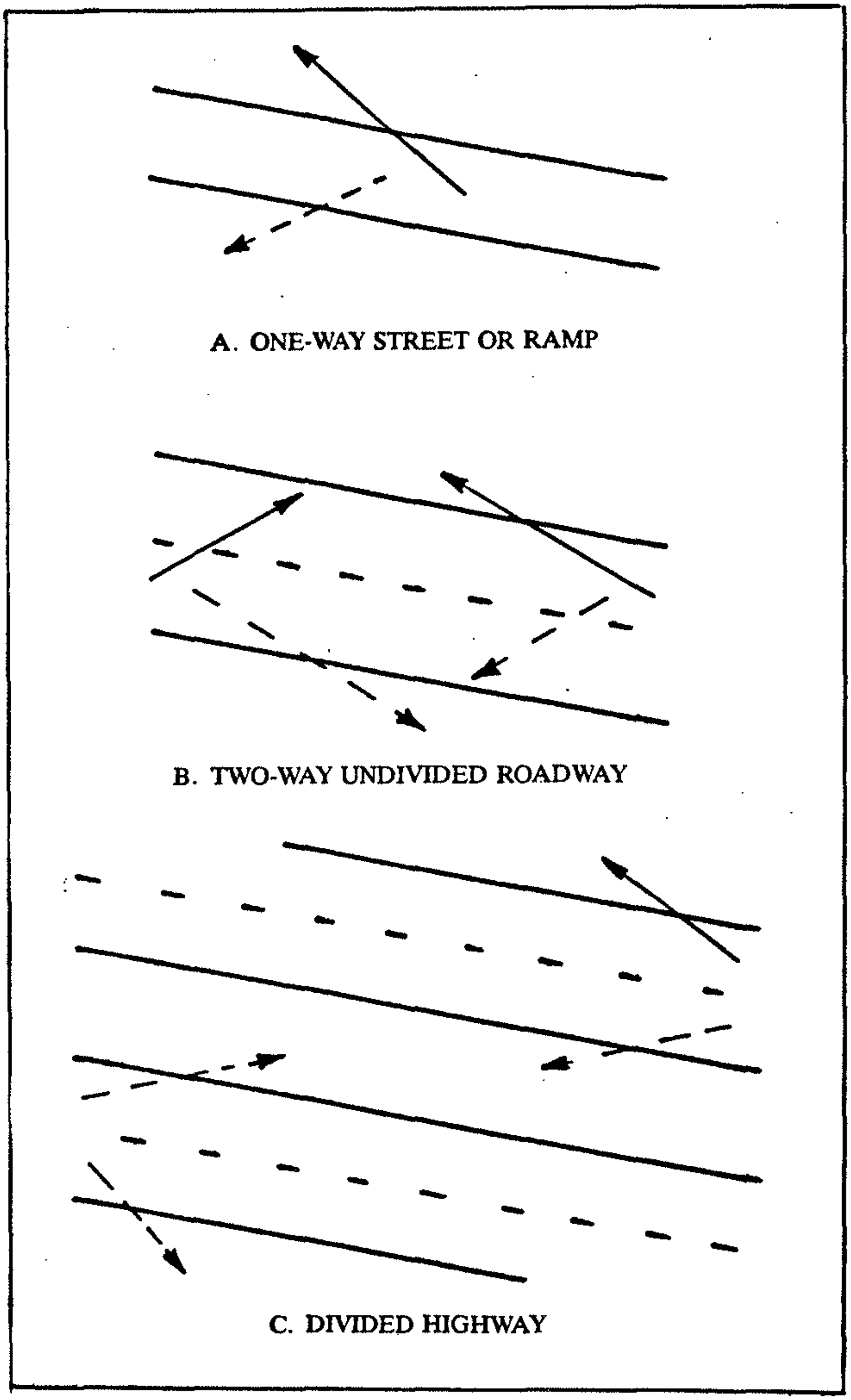


FIGURE 35. ENCROACHMENTS BY ROADWAY TYPE.

10.5.2 Number of Lanes and Lane Width

These input values are used to calculate encroachments from adjacent traffic if there is more than one lane, and encroachments from opposite flowing traffic if the highway is undivided.

10.5.3 Curvature and Grade Factors

The number of baseline encroachments calculated by the computer model assumes a straight and level roadway. The model allows for adjustment by the use of a curvature factor (K_c) or a grade factor (K_g), whichever may apply. These factors are expressed graphically in Figure 36 (19).

10.5.4 User Factor

If the encroachment rate is influenced by any other conditions other than grade or curvature, the designer may use a subjective factor to modify the number of baseline encroachments accordingly.

10.5.5 Design Speed

The computer model will accept design speeds of 40 mph, 50 mph, 60 mph, and 70 mph and round all other values to the next higher speed. The design speed is needed to select the proper probability curve, as shown in Figure 37 (19).

10.5.6 Hazard Definition

A hazard is defined by the model as being any object along the roadside including a traffic barrier installed to shield a fixed object. The hazard is represented by a rectangle with a length (L) parallel to the roadway, a width (W), and an offset (A) from the edge of the adjacent lane. The methodology employs hazard model theory, as shown in Figure 38.

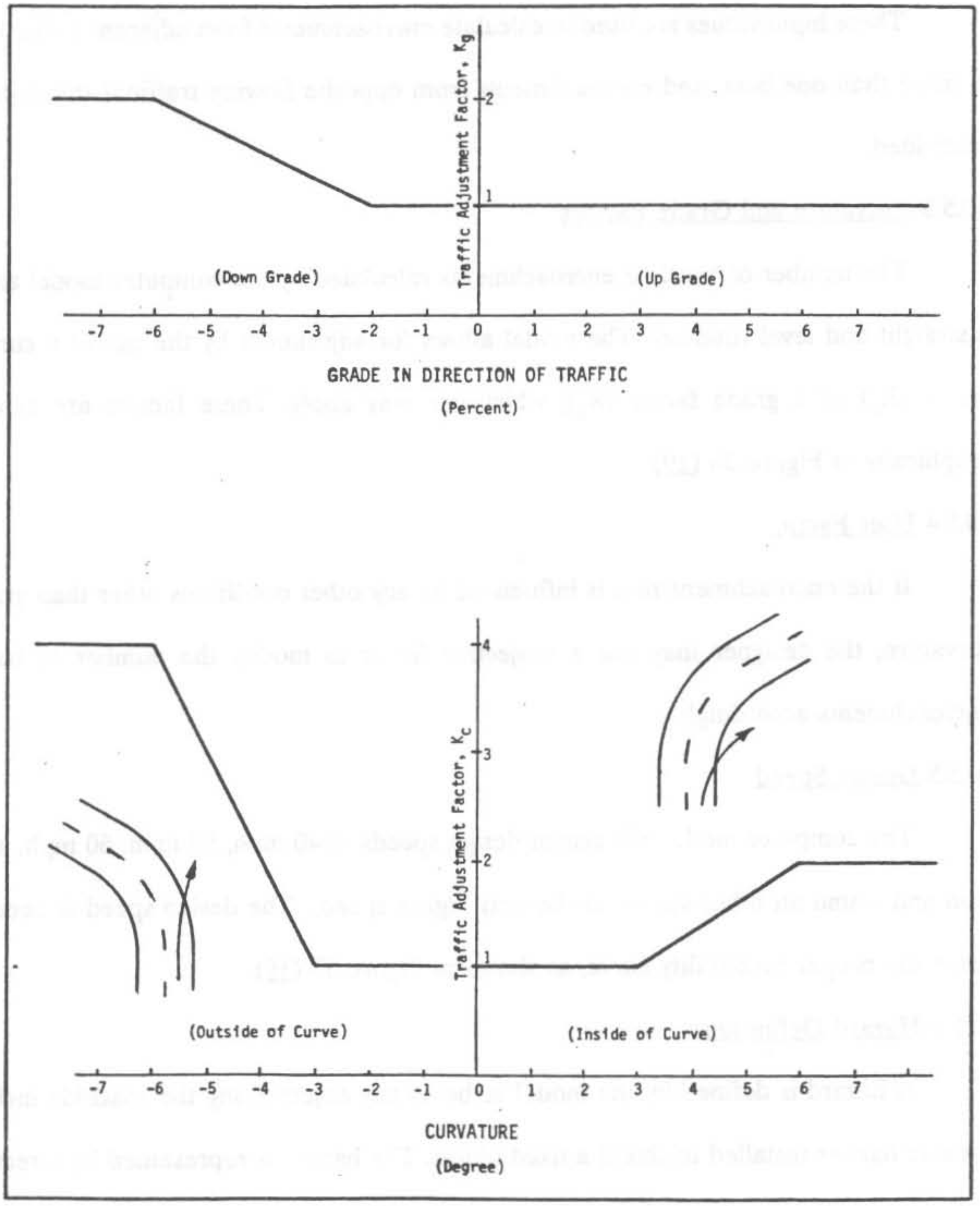


FIGURE 36. ENCROACHMENT ADJUSTMENT FACTORS FOR ROADWAY CURVATURE AND GRADE.

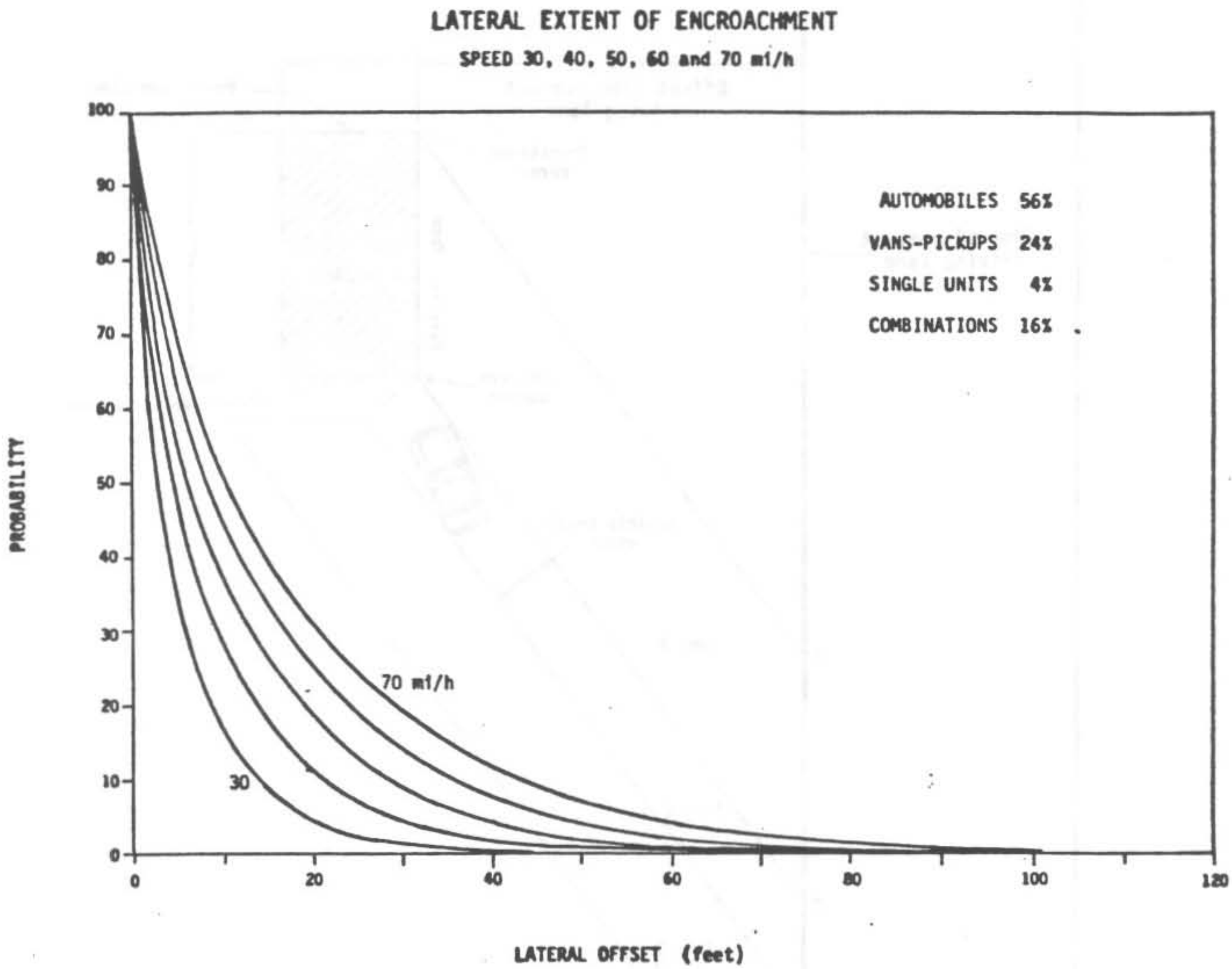


FIGURE 37. LATERAL EXTENT OF ENCROACHMENT PROBABILITY CURVES.

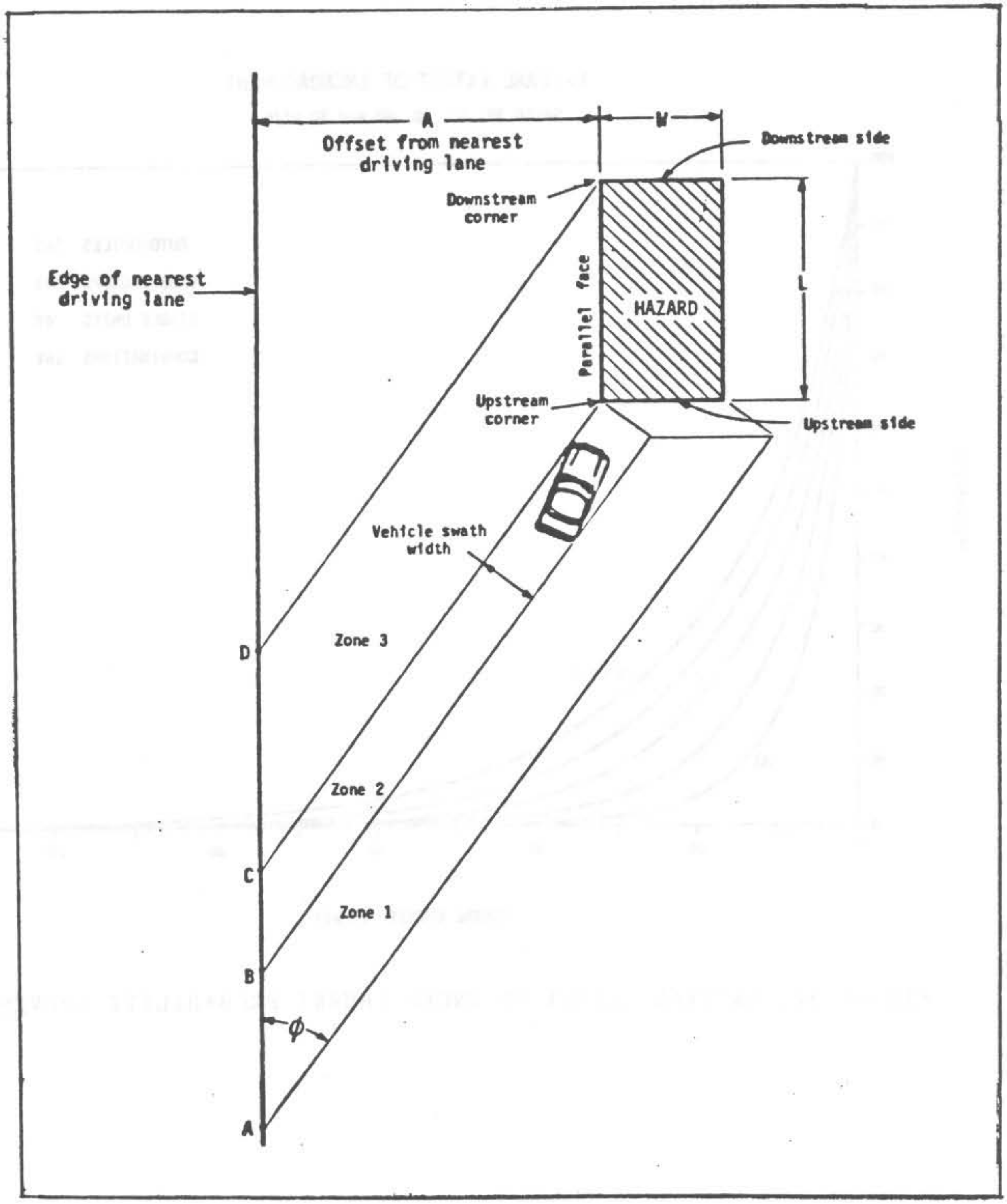


FIGURE 38. HAZARD MODEL FOR ADJACENT TRAFFIC.

10.5.7 Accident Costs

The accident costs used in the model to determine the costs of accidents of various severities are as follows:

Fatality	$ 1,500,000
Severe Personal Injury	$ 110,000
Moderate Personal Injury	$ 11,000
Slight Personal Injury	$ 3,000
Property Damage Only (Level 2)	$ 3,000
Property Damage Only (Level 1)	$ 500

10.5.8 Severity Index

The purpose of the severity index (SI) is to convert the accident data into cost data. This conversion is accomplished by assigning values to different areas of the hazard, more specifically, the upstream and downstream sides, upstream and downstream corners, and the face.

Suggested values for the severity index for rigid objects are shown in Table 14 (44); the values vary according to the design speed. The selection of a severidy index (*SI*) is relatively subjective and represents an average severity. The value can be based upon local data if any is available. Figure 39 shows the relationship between accident cost and severity indices.

10.6 Global Values

The global values should remain constant for the study and are entered separately.

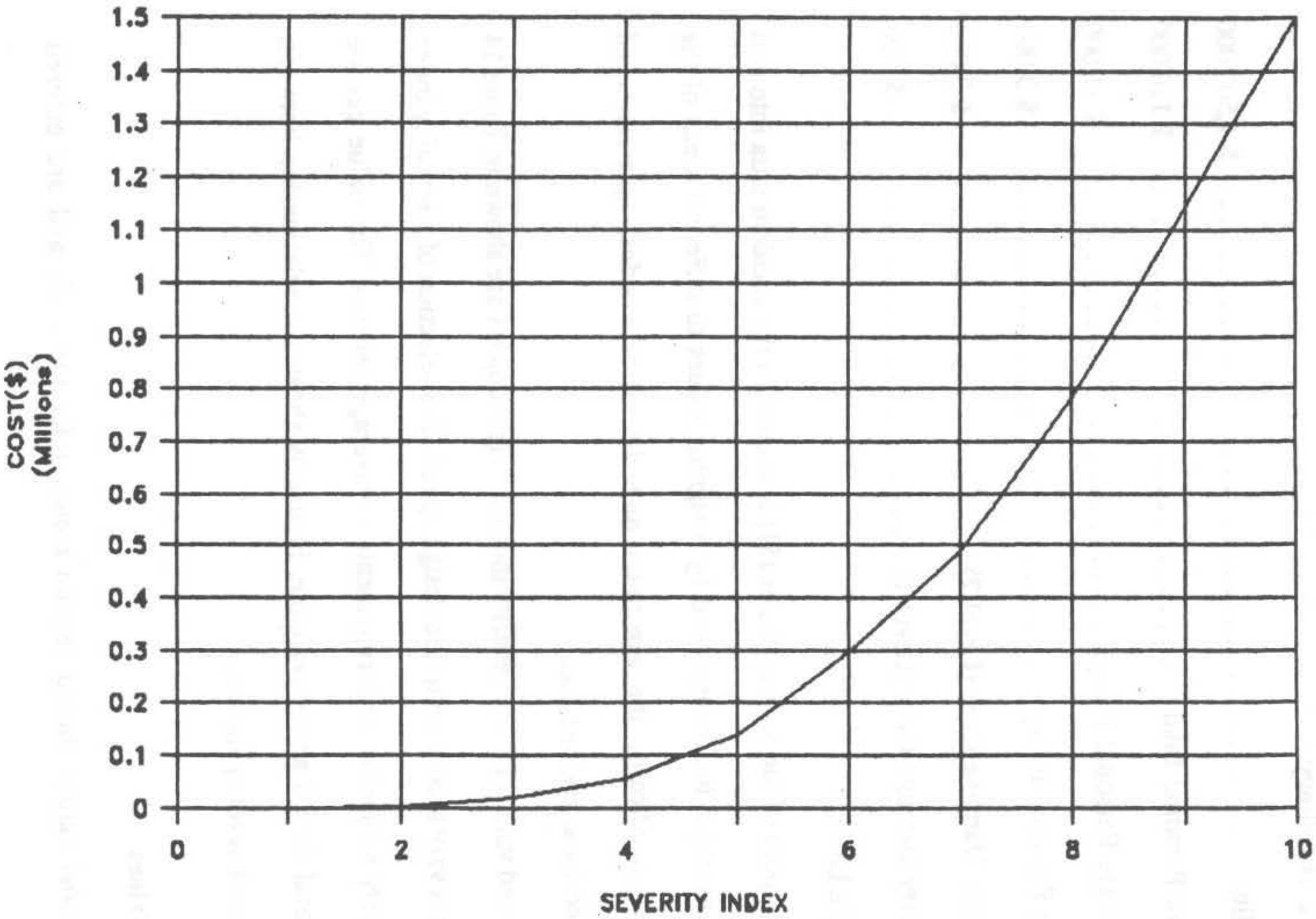


FIGURE 39. GRAPH OF COST VS. SEVERITY INDEX.

TABLE 14

Severity Indices

TYPE OF HAZARD	FACE SIDE BOTH	40 MPH		50 MPH		60 MPH		70 MPH	
		RANGE	AVG.	RANGE	AVG.	RANGE	AVG.	RANGE	AVG.
RIGID OBJECTS									
Rigid (nonfrangible)	Both	2.6 - 5.0	3.8	3.2 - 6.0	4.6	3.8 - 7.2	5.5	4.4 - 8.6	6.5
Frangible or Breakaway	Both	0.4 - 2.6	1.5	0.6 - 3.2	1.9	0.8 - 3.8	2.3	1.0 - 4.4	2.7
Variable Height									
Height < 4"	Both	0.6 - 1.0	0.8	1.0 - 1.8	1.4	1.4 - 2.4	1.9	1.8 - 3.0	2.4
Height = 4"-10"	Both	1.0 - 2.6	1.8	1.8 - 3.2	2.5	2.4 - 3.6	3.0	3.0 - 4.4	3.7
Height > 10"	Both	2.6 - 5.0	3.8	3.2 - 6.0	4.6	3.8 - 7.2	5.5	4.4 - 8.6	6.5
Edge Drop-Off									
Height < 4"	Both	0.4 - 1.0	0.7	0.6 - 1.4	1.0	0.8 - 1.8	1.3	1.0 - 2.2	1.6
Height = 4"-10"	Both	1.0 - 1.6	1.3	1.4 - 2.2	1.8	1.8 - 2.8	2.3	2.2 - 3.6	2.8

FACTORS THAT EFFECT SEVERITY RANGE

Low Range:
Object on fill slope (uphill) non-frangible diameter is small, proper design/ placement and mainte-nance of frangible object, top of base flush with ground, no erosion around base.

High Range:
Object on 6:1 or steeper slope (non-recoverable), non-frangible diameter is large, improper placement/ design of post, base located at hinge, erosion around base improper maintenance of sign support and breakaway device.

10.6.1 Fatality, Injury, and Damage Costs

These costs were described in an earlier section.

10.6.2 Encroachment Rate

The basic encroachment rate used by the computer model is a linear function of traffic volume. Suggested encroachment rates are shown in Table 15 (28).

10.6.3 Encroachment Angle

The encroachment angles have been generalized for the use in "ROADSIDE" and are classified according to the design speed.

10.6.4 Limiting Traffic Volume/Lane

The model uses 10,000 vehicles per lane; as traffic volumes increase above this level the model assumes that operating speeds, the number of encroachments, and the level of service decrease.

10.6.5 Swath Width

The width is known as the effective width of the vehicle; it is based on the length and width of a full size passenger car and the assumed yaw angle.

TABLE 15

Vehicle Encroachment Rate as a Function of Highway Classification and Traffic Volume

Nebraska Highway Design Number	Highway Classification	Encroachment Rate for Both Direction of Travel (encroachments/mile/year)
DR 1	Rural Interstate and Expressway	0.000900 ADT
DR 2	Rural Multilane	0.000590 ADT
DR 3	Divided Highway	0.000590 ADT
DR 4	Wide Rural	0.000742 ADT
DR 5	Two-Lane Highway	0.000742 ADT
DR 6	(Roadbed ≥ 36 ft)	0.000742 ADT
DR 7	Narrow Rural Two-Lane Highway (Roadbed < 36 ft)	0.001210 ADT
DR 10	Urban Interstate	0.000900 ADT
DM 20		0.000900 ADT
DM 30	Urban Multilane	0.000900 ADT
DM 40	Divided Highway	0.000900 ADT
DM 50	Urban Major Arterial	0.001330 ADT
DM 60	Street	0.001330 ADT
ADT = Average Daily Traffic		

11 "ROADSIDE" GENERAL SITE ANALYSES

11.1 Introduction

The general site analysis approach was used in combination with one specific site analysis to perform the benefit-to-cost analysis using the "ROADSIDE" computer model. The general site represents a typical urban location in Nebraska. The specific site analysis was located in Wayne, Nebraska and will be discussed in further detail in Chapter 12.

In contrast with the specific site analysis, which is an example of a single installation, the general site analyses were assumed single installations. They were not treated as a line of utility installations but as individual roadside hazards. The shapes of particular installations were approximated in order to comply with the roadside hazard model.

11.2 Objective

Since the effects of relocation, removal, and breakaway conversion were not evident, the objective was to discover the effects using a benefit-to-cost analysis. The analysis involved using a typical or general site representing urban Nebraska. The benefit-to-cost analysis was based upon the "ROADSIDE" computer model which computes annualized costs, such as installation, repair, maintenance, and accident costs. After analyzing these costs, a benefit-to-cost ratio could be calculated which could aid in determining a minimum lateral obstacle clear zone for utility installations. At the same time, an evaluation would be made analyzing the economics of the relocation, removal, and breakaway scenarios.

The major objective was to determine the most cost-effective roadside appurtenance lateral offset, and at the same time gain experience and knowledge working with the "ROADSIDE" computer model.

After determining the benefit-to-cost ratios for a given countermeasure, the results were expressed graphically. Such graphic representation is helpful in selecting the optimum location to locate a single utility installation; that is, the safe location of a luminaire, utility pole, fire hydrant, or breakaway appurtenance of previously mentioned installations.

11.3 Scope

The general site analyses were performed with seven different utility installation scenarios for the same general field location. The seven utility installations were as follows:

(1) Basic Light Poles
(2) Type 1 Power Poles
(3) Type 2 Power Poles
(4) Type 3 Power Poles
(5) Type 4 Power Poles
(6) Type 5 Power Poles
(7) Basic Fire Hydrants

The power poles were identified by "Type" for calculation purposes during the computer analyses; the types were based upon various installation costs (Table 16). The basic scenario was the relocation of the existing utility installation. For utility installations 1, 2, and 7, the breakaway conversion was also incorporated into the evaluation.

TABLE 16

Typical Installation, Maintenance, and Repair Costs for Utility and Light Poles

Installation Type	Costs ($) Installation	Maintenance	Salvage	Repair
Basic Light Pole				
(a) Rigid	650	10	0	1,000
(b) Breakaway	750	10	0	350
Type 1 Power Pole				
(a) Rigid	1,700	0	0	0
(b) Breakaway	2,675	0	0	1,338
Type 2 Power Pole	3,500	0	0	0
Type 3 Power Pole	8,350	0	0	0
Type 4 Power Pole	14,850	0	0	0
Type 5 Power Pole	28,850	0	0	0

The description of the power pole types is as follows:

(1) Type 1 Power Distribution Pole
- (a) Local and Large Distribution
- (b) 1-3 Phase
- (c) Wood Pole

(2) Type 2 Power Distribution Pole
- (a) Large Distribution
- (b) Heavy 3 Phase
- (c) 4-13.8 KV
- (d) Wood Pole

(3) Type 3 Power Transmission Pole
- (a) 35-69 KV (Wood)

(4) Type 4 Power Transmission Pole
- (a) 35-69 KV (Steel)
- (b) 35 KV (Wood) Plus Distribution Underbuilt

(5) Type 5 Power Transmission Pole
- (a) 115-161 KV (Steel)
- (b) 115 KV (Steel) Plus Distribution Underbuilt

The global values for every installation remained constant throughout the entire evaluation. The global values are listed below:

Global Values

Fatality	$ 1,500,000
Severe Personal Injury	$ 110,000
Moderate Personal Injury	$ 11,000
Slight Personal Injury	$ 3,000
Property Damage Only (Level 2)	$ 3,000
Property Damage Only (Level 1)	$ 500
Encroachment Rate (encroachments/mile/year/vpd)	$ 0.00133
Encroachment Angle at 40 mph	17.2 degrees
Limiting Traffic Volume/Lane	10,000 vpd
Swath Width	12 feet

The variable data inputs that remain constant are as follows:

Lane Width	15 feet
Roadway Curvature	0 degrees
Roadway Grade	0 degrees
User Adjustment Factor	1.0
Design Speed	40 mph
Project Life	20 years
Discount Rate	8%
Traffic Growth Rate (TGR)	2%
Salvage Value	$0

The computer test matrix is shown in Table 17. For each of the single utility installation types, a computer run was made for the following ADT's: 5000, 10000, 20000, 30000, and 40000 for both a two-lane and four-lane roadway. The relocation countermeasures were conducted with the original installation located at a lateral offset of 2 ft and then relocated to a final offset ranging from 3 ft to 10 ft in increments of 1 ft. An analysis was also performed for the do-nothing alternative.

TABLE 17

"ROADSIDE" Computer Runs Matrix

Type of Hazard	ADT (vpd)										Breakaway		Total
	5000		10000		20000		30000		40000				
	2-Lane	4-Lane	2-Lane	4-Lane	2-Lane	4-Lane	2-Lane	4-Lane	2-Lane	4-Lane	2-Lane	4-Lane	2nd & 4th Lane
Light Poles	9	9	9	9	9	9	-	9	-	9	5	5	82
1. Power District Poles 1-3 Phase 4-13.8 KV (wood)	9	9	9	9	9	9	-	9	-	9	5	5	82
2. Power District Poles Heavy 3-Phase 4-13.8 KV (wood)	9	9	9	9	9	9	-	9	-	9	-	-	72
3. Power Transmission Poles 36-69 KV (wood)	9	9	9	9	9	9	-	9	-	9	-	-	72
4. Power Trans. 36-59 KV (steel) + Power Trans. Dist. 35 KV (wood)	9	9	9	9	9	9	-	9	-	9	-	-	72
5. Power Trans. 115-161 KV (steel) Power Trans + Dist. 115 KV (steel)	9	9	9	9	9	9	-	9	-	9	-	-	72
Fire Hydrant	9	9	9	9	9	9	-	9	-	9	5	5	82
											TOTAL RUNS		534

Note:

1. Relocation: # Runs = Original 2 ft offset plus relocation from 3 ft to 10 ft with 1 ft increments = 9 runs.

2. Breakaway: # Runs = Conversion to a breakaway with each of the experimental ADT's = 5 runs.

The computer runs for two-lane roadways having ADT's equal to 30000 and 40000 were the same as for runs having an ADT equal to 20000 since the global limiting traffic volume per lane variable was set at 10,000 vehicles/lane. This value was selected because a traffic volume greater than 10,000 vehicles/lane will most likely cause traffic speeds to decrease; encroachments will most likely decrease as well. The analyses of the seven different utility installation scenarios are discussed below.

11.4 Test Results

The basic scenarios were the same for all seven installations using the general site analysis. The first scenario included relocating the original installation from the lateral offset of 2 ft to the final lateral offset of 10 ft in 1 ft increments. This process was performed with the following ADT's (5000, 10000, 20000, 30000, 40000) on two-lane undivided and four-lane divided roadways. The second scenario consisted of the conversion of light poles, type 1 power poles, and fire hydrants to breakaway installations using the 2 ft offset and varying the following ADT's (5000, 10000, 20000, 30000, 40000).

Example computer runs are provided in Appendices M and N. The example in Appendix M shows relocation alternatives using an ADT of 5000 on a two-lane, undivided roadway. An example of a breakaway conversion using the original 2 ft lateral offset with ADT's of 5000, 10000, 20000, 30000, and 40000 is shown in Appendix N. Finally, Appendix O provides two examples of benefit-to-cost ratio calculations using the output from these two computer runs.

11.5 Street Lighting

The first utility installation type analyzed with the general site analysis was the light pole relocation. The results presented in Figures 40, 41, and 42 represent two-lane and four-lane roadways.

11.5.1 Relocation (two-lane undivided)

Any of the relocation distances would be cost-effective since the benefit-to-cost ratios were greater than 1.0 (Figure 40). The values for the benefit-to-cost ratios at an ADT of 20000, 30000, and 40000 were equal because of the effect of the traffic volume limit of 10,000 vehicles per lane. Since all the benefit-to-cost ratios were greater than 1.0, it was difficult to determine an adequate minimum lateral offset.

11.5.2 Relocation (four-lane divided)

The results presented in Figure 41 indicate that all relocation distances would be cost-effective on four-lane roadways. The leveling off of the curves for a lateral offset of 8 ft and ADT's of 5000 and 10000 shows the effect of the benefit reaching its maximum and the cost remaining constant. The benefit-to-cost ratios continue to increase for the larger ADT's.

11.5.3 Breakaway Street Lighting

As in the previous case, since the benefit-to-cost ratios were all greater than 1.0 it would be cost-effective to convert the street light pole to become breakaway at any of the analyzed ADT's (Figure 42). The benefit-to-cost ratios become constant after an ADT of 20000 for the two-lane roadway; once again, this was due to the effect of the traffic volume limit of 10000 vehicles per lane.

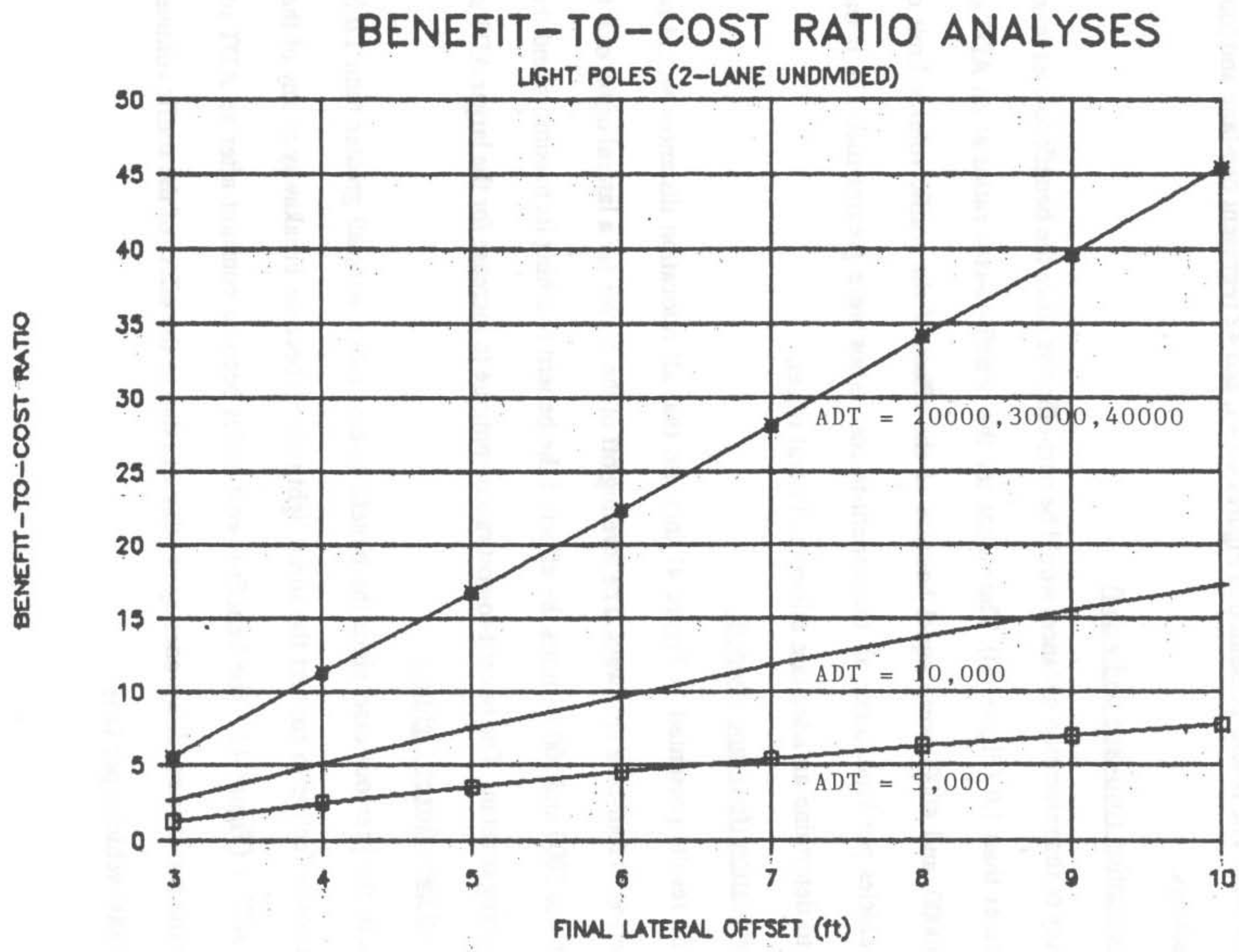


FIGURE 40. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR LIGHT POLES (2-LANE).

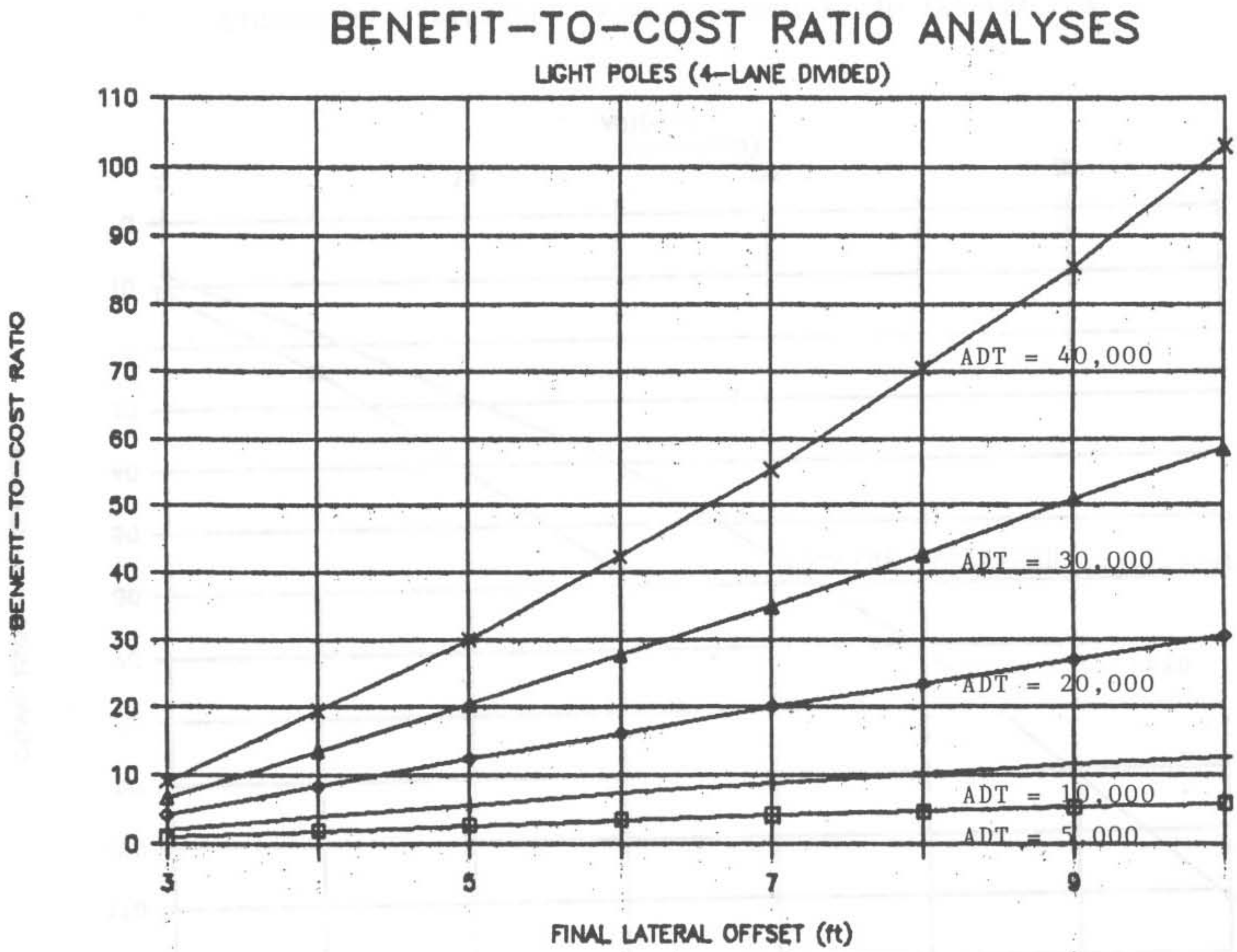


FIGURE 41. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR LIGHT POLES (4-LANE).

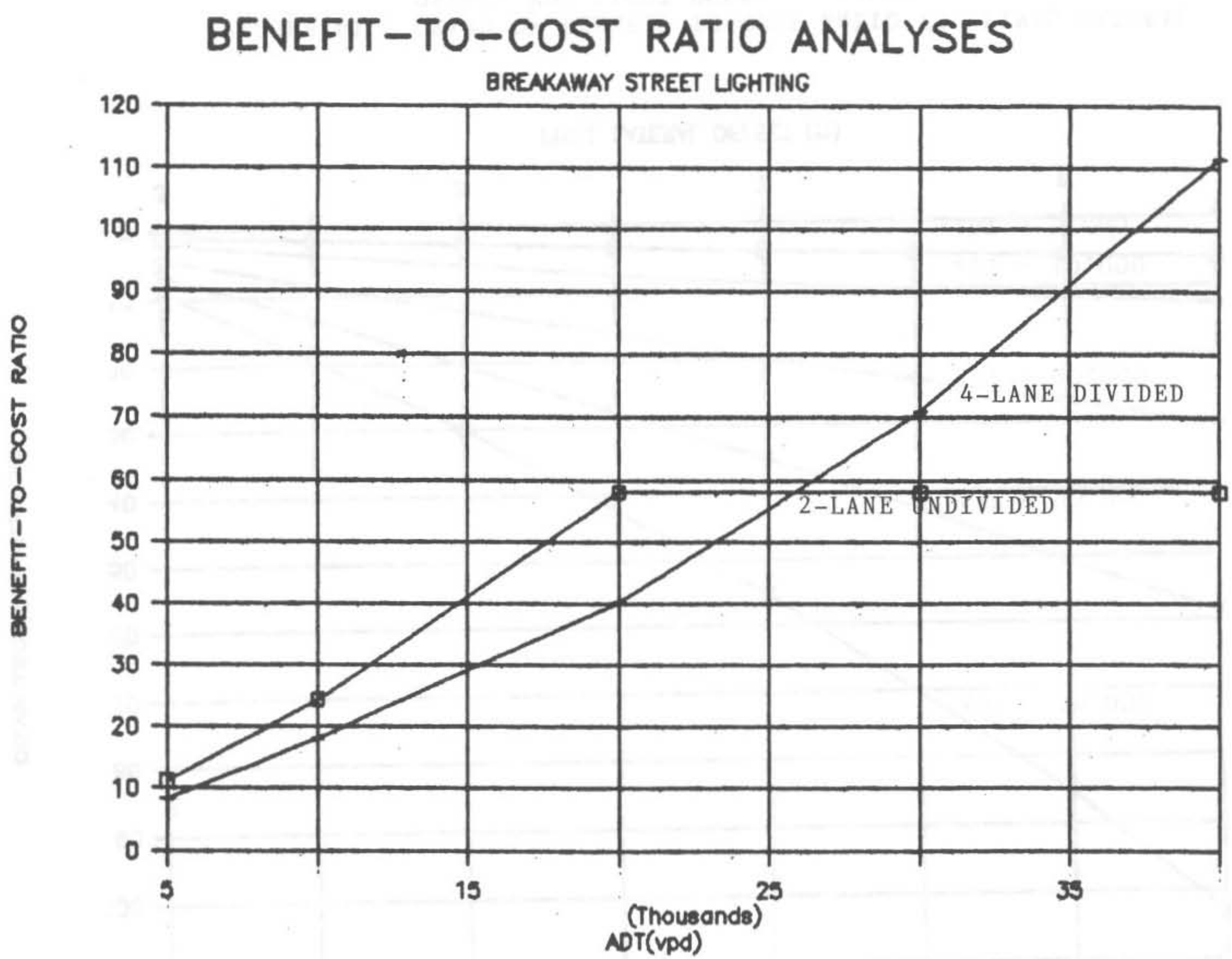


FIGURE 42. GRAPH OF BENEFIT-TO-COST RATIO VS. ADT FOR BREAKAWAY LIGHT POLES.

11.5.4 Relocation Vs. Breakaway (Light Poles)

In order to determine if there was a location at which a relocation countermeasure was more cost-effective than the breakaway conversion countermeasure, or vice versa, a comparison was performed for each of the countermeasures. ADT's of 10000 and 40000 on a four-lane divided roadway were used for the comparison. The procedure, known as incremental benefit-to-cost ratio analysis, is shown below.

ADT = 10000 (4-lane, divided)

Countermeasure	EUAC	EUAB	B/C	Incremental B/C
1. 2 ft to 3 ft	64	134	2.09	
Breakaway @ 2 ft	68	1,227	18.04	273.2
2. 2 ft to 4 ft	63	253	4.02	
Breakaway @ 2 ft	68	1,227	18.04	94.8
3. 2 ft to 5 ft	62	354	5.71	
Breakaway @ 2 ft	68	1,227	18.04	145.5
4. 2 ft to 6 ft	60	446	7.43	
Breakaway @ 2 ft	68	1,227	18.04	97.6
5. 2 ft to 7 ft	59	526	8.92	
Breakaway @ 2 ft	68	1,227	18.04	77.9
6. 2 ft to 8 ft	58	598	10.31	
Breakaway @ 2 ft	68	1,227	18.04	62.9
7. 2 ft to 9 ft	57	663	11.63	
Breakaway @ 2 ft	68	1,227	18.04	51.3
8. 2 ft to 10 ft	57	721	12.65	
Breakaway @ 2 ft	68	1,227	18.04	46.0

ADT = 40000 (4-lane, divided)

Countermeasure	EUAC	EUAB	B/C	Incremental B/C
1. Breakaway @ 2 ft	44	4,908	111.54	
2 ft to 3 ft	59	538	9.12	-291.3
2. Breakaway @ 2 ft	44	4,908	111.54	
2 ft to 4 ft	52	1,014	19.50	-486.8
3. Breakaway @ 2 ft	44	4,908	111.54	
2 ft to 5 ft	47	1,419	30.19	-1,163.0
4. 2 ft to 6 ft	42	1,784	42.47	
Breakaway @ 2 ft	44	4,908	111.54	1,562.0
5. 2 ft to 7 ft	38	2,104	55.36	
Breakaway @ 2 ft	44	4,908	111.54	467.3
6. 2 ft to 8 ft	34	2,395	70.44	
Breakaway @ 2 ft	44	4,908	111.54	251.3
7. 2 ft to 9 ft	31	2,651	85.51	
Breakaway @ 2 ft	44	4,908	111.54	173.6
8. 2 ft to 10 ft	28	2,885	103.03	
Breakaway @ 2 ft	44	4,908	111.54	126.4

The incremental benefit-to-cost ratio analysis contrasted the relocation and breakaway countermeasures. The lowest cost alternative served as the basis for the comparison. If the countermeasure being compared to the base had a benefit-to-cost ratio greater than or equal to 1.0, then the countermeasure with the higher cost was selected.

The first analysis compared relocation to breakaway at an ADT of 10000. All the relocation countermeasures had an EUAC less than the breakaway countermeasure; therefore, the relocation alternatives were selected as the base alternatives. When comparing the higher cost alternative (breakaway) to the base option, the benefit-to-cost ratios were all greater than 1.0. The best alternative was thus the breakaway alternative.

The second analysis compared relocation to breakaway at an ADT of 40000. It was evident that the base alternative was not the same throughout the analysis, and therefore the method of comparison changed throughout the analysis. For relocations up to 5 ft, the lower cost alternative was the breakaway option. After a relocation of 6 ft, the relocation option was the lower cost alternative (base option). Although the base option changed, the final outcome remained the same: the best alternative was the breakaway option.

11.6 Type 1 Power Pole

The general site analysis was also used to analyze a second utility installation, the Type 1 Power Pole. The results presented in Figures 43, 44, and 45 represent two-lane and four-lane roadways. The costs for the alternatives are shown in Table 16.

11.6.1 Relocation (two-lane undivided)

The results presented in Figure 43 show that a pole relocation of any distance would be cost-effective when the ADT is 10000 or larger. When analyzing the 6 ft minimum standard, a minimum ADT of approximately 3000 would be required for the relocation to be cost-effective.

The benefit-to-cost ratios are not as high for power poles as for street light poles because of the higher costs of the former. The benefit-to-cost ratios do continue to increase, however, but at a decreasing rate. There was also no strong indication of an optimum minimum lateral offset distance.

11.6.2 Relocation (four-lane divided)

The results presented in Figure 44 show that a pole relocation of any distance would be cost-effective when an ADT of 13000 or greater exists. When analyzing the 6 ft minimum standard, a minimum ADT of approximately 4000 would be required for the relocation to be cost-effective.

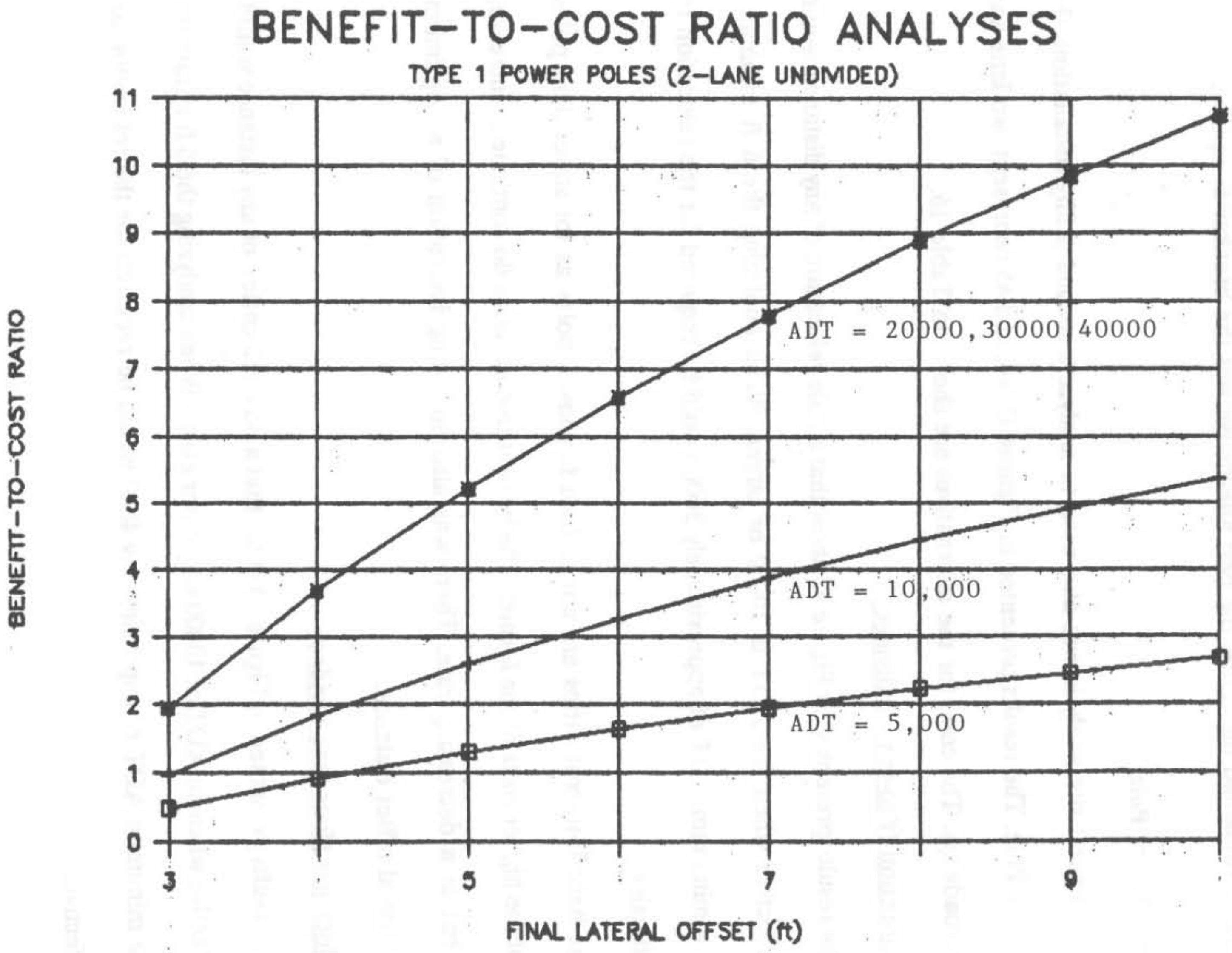


FIGURE 43. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 1 POWER POLES (2-LANE).

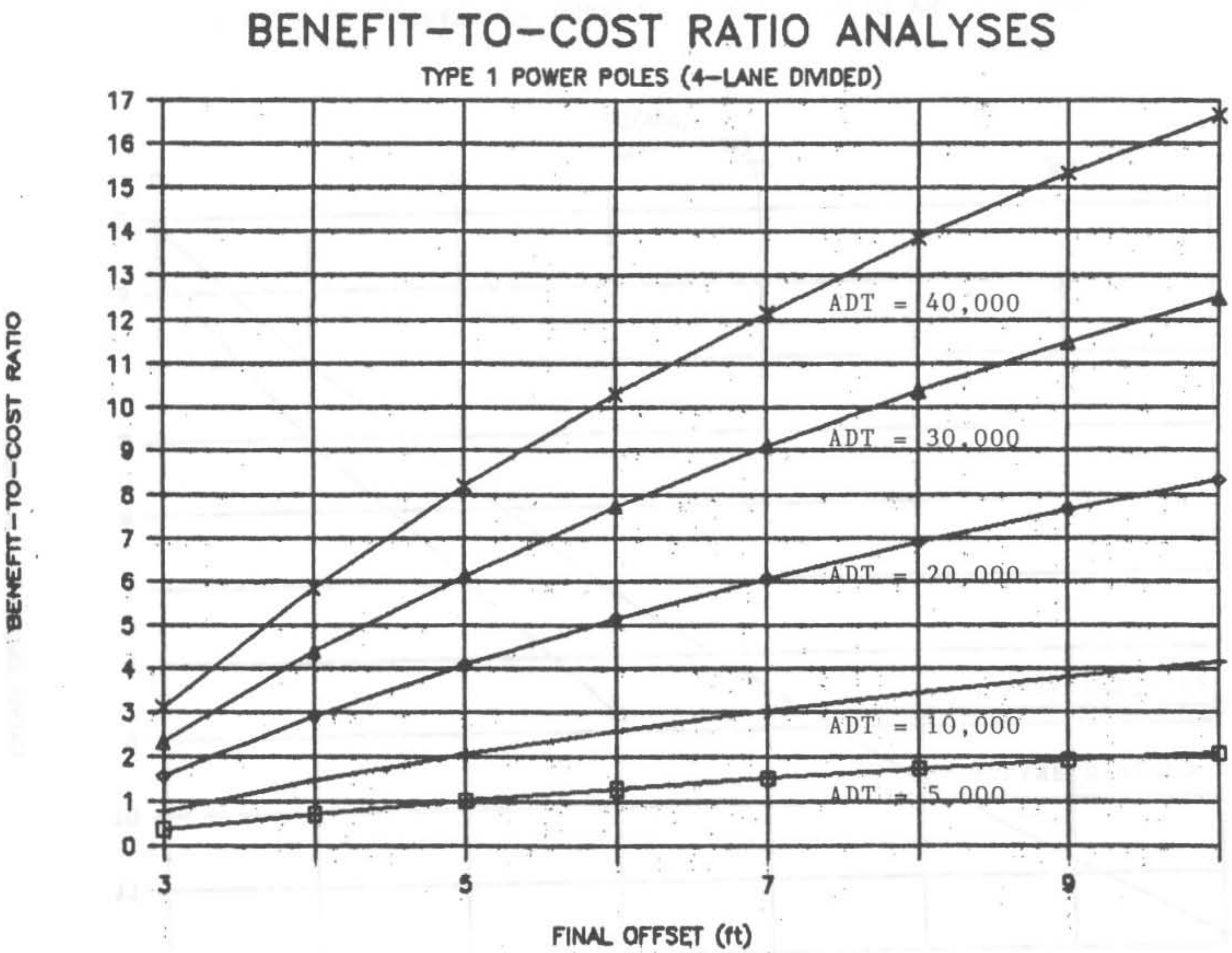


FIGURE 44. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 1 POWER POLES (4-LANE).

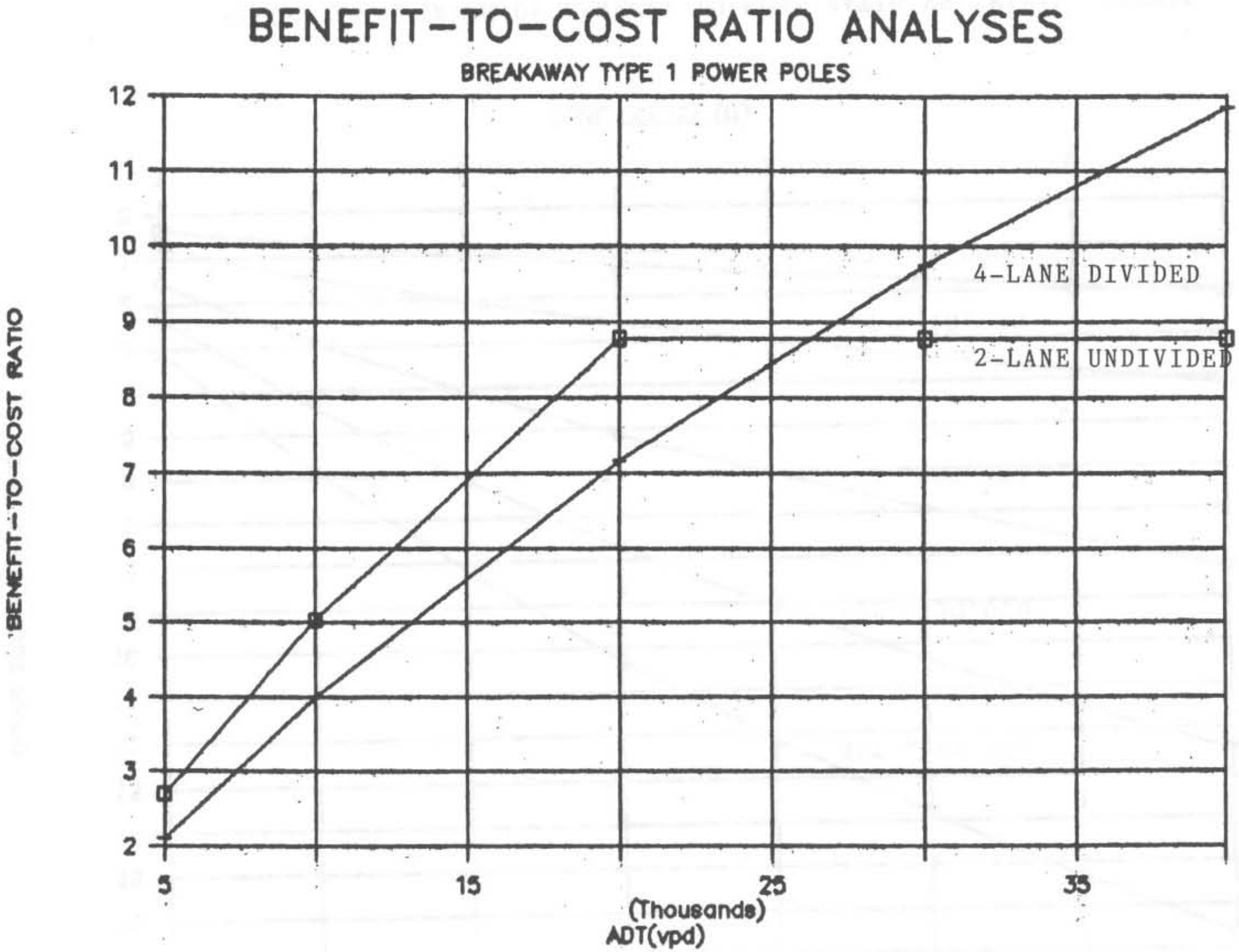


FIGURE 45. GRAPH OF BENEFIT-TO-COST RATIO VS. ADT FOR BREAKAWAY POWER POLES.

The benefit-to-cost ratios begin to level off for the ADT's of 5000 and 10000 for relocation distances up to 10 ft. For the ADT's greater than 10000, the benefit-to-cost ratios continue to increase at a decreasing rate.

11.6.3 Breakaway Type 1 Power Poles (two-lane and four-lane)

The results presented in Figure 45 show that it would be cost-effective to convert Type 1 power poles to be breakaway for all ADT's from 5000 to 40000. The benefit-to-cost ratios become constant after an ADT of 20000 for the two-lane roadway. Once again, this was due to the effect of the traffic volume limit of 10000 vehicles per lane.

11.6.4 Relocation Vs. Breakaway (Type 1 Power Poles)

The incremental benefit-to-cost ratio analysis procedure was used to compare location and breakaway alternatives for ADT's of 10000 and 40000 on a four-lane divided roadway. The analysis is shown below.

ADT = 40000 10000 (4-lane, divided)

Countermeasure	EUAC	EUAB	B/C	Incremental B/C
1. 2 ft to 3 ft	173	134	0.77	
Breakaway @ 2 ft	307	1,227	3.99	8.2
2. 2 ft to 4 ft	173	253	1.46	
Breakaway @ 2 ft	307	1,227	3.99	7.3
3. 2 ft to 5 ft	173	354	2.04	
Breakaway @ 2 ft	307	1,227	3.99	6.5
4. 2 ft to 6 ft	173	446	2.58	
Breakaway @ 2 ft	307	1,227	3.99	5.8
5. 2 ft to 7 ft	173	526	3.04	
Breakaway @ 2 ft	307	1,227	3.99	5.2
6. 2 ft to 8 ft	173	598	3.45	
Breakaway @ 2 ft	307	1,227	3.99	4.7
7. 2 ft to 9 ft	173	663	3.83	
Breakaway @ 2 ft	307	1,227	3.99	4.2
8. 2 ft to 10 ft	173	721	4.16	
Breakaway @ 2 ft	307	1,227	3.99	3.8

ADT = 40000 (4-lane, divided)

Countermeasure	EUAC	EUAB	B/C	Incremental B/C
1. 2 ft to 3 ft	173	538	3.12	
Breakaway @ 2 ft	414	4,908	11.86	18.1
2. 2 ft to 4 ft	173	1,014	1.46	
Breakaway @ 2 ft	414	4,908	11.86	16.2
3. 2 ft to 5 ft	173	1,419	2.04	
Breakaway @ 2 ft	414	4,908	11.86	14.5
4. 2 ft to 6 ft	173	1,784	2.58	
Breakaway @ 2 ft	414	4,908	11.86	13.0
5. 2 ft to 7 ft	173	2,104	3.04	
Breakaway @ 2 ft	414	4,908	11.86	11.6
6. 2 ft to 8 ft	173	2,395	3.45	
Breakaway @ 2 ft	414	4,908	11.86	10.4
7. 2 ft to 9 ft	173	2,651	3.83	
Breakaway @ 2 ft	414	4,908	11.86	9.4
8. 2 ft to 10 ft	173	2,885	4.16	
Breakaway @ 2 ft	414	4,908	11.86	8.4

The incremental benefit-to-cost ratio analysis contrasted the relocation and breakaway countermeasures. The lowest cost alternative was the basis for the comparison. If the countermeasure which was being compared to the base had a benefit-to-cost ratio greater than or equal to 1.0, then the countermeasure with the higher cost was selected.

The first analysis compared relocation to breakaway at an ADT of 10000. All the relocation countermeasures had an EUAC less than the breakaway countermeasure; therefore, the relocation countermeasures were selected as the base alternatives. When comparing the higher cost alternative (breakaway) to the base option, the benefit-to-cost ratios were all greater than 1.0. The best alternative was thus the breakaway alternative.

The second analysis compared relocation to breakaway at an ADT of 40000. It was evident that the relocation option was the base alternative. The analysis indicated that the breakaway option was the better alternative when compared to relocation of various offsets.

11.7 Type 2 Power Poles

The third utility installation which was analyzed using the general site analysis was the Type 2 Power pole. The results presented in Figures 46 and 47 represent two-lane and four-lane roadways. The costs for the alternatives are shown in Table 16.

11.7.1 Relocation (two-lane undivided)

The results of the benefit-to-cost ratio analysis are presented in Figure 46. For a cost-effective countermeasure with ADT's from 5000 to 40000, it was evident that a relocation of 8 ft or greater would have to be implemented. When analyzing the 6 ft minimum standard, a minimum ADT of approximately 6000 would be required for the relocation to be cost-effective. The curves increase at a decreasing rate, and the benefit-to-cost ratios begin to level off only at a low ADT, such as 5000 or less. Therefore, no optimum lateral obstacle offset distance was indicated.

11.7.2 Relocation (four-lane divided)

The results of the benefit-to-cost ratio analysis are presented in Figure 47. For a cost-effective countermeasure with ADT's from 5000 to 40000, it was evident that a relocation of 10 ft or greater would have to be implemented. When analyzing the 6 ft minimum standard, a minimum ADT of approximately 8000 would be required for the relocation to be cost-effective. The curves increase at a decreasing rate and the benefit-to-cost ratios begin to level off only at a low ADT, such as 5000 to 10000. Thus, the maximum effective lateral offset distance would be approximately 10 ft.

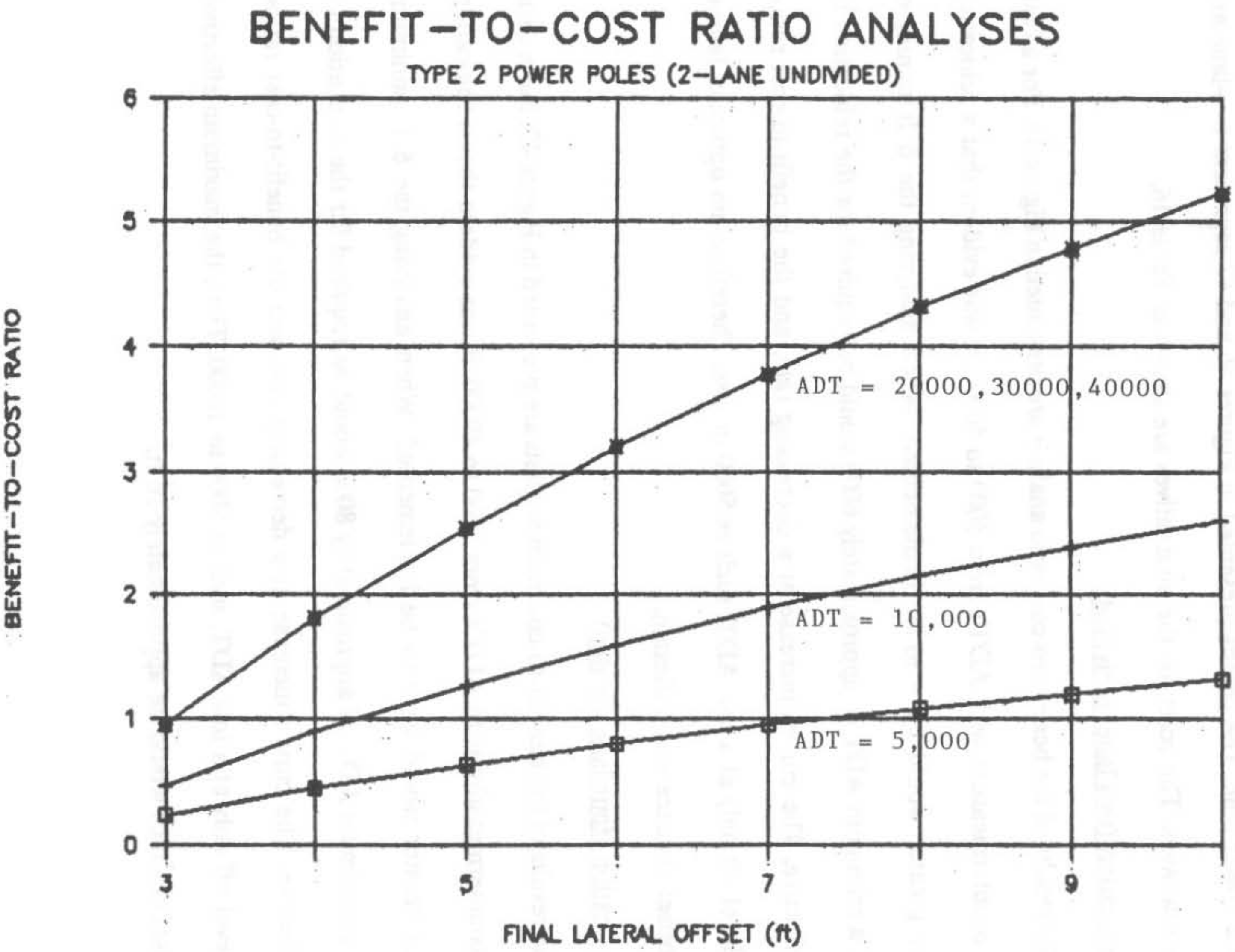


FIGURE 46. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 2 POWER POLES (2-LANE).

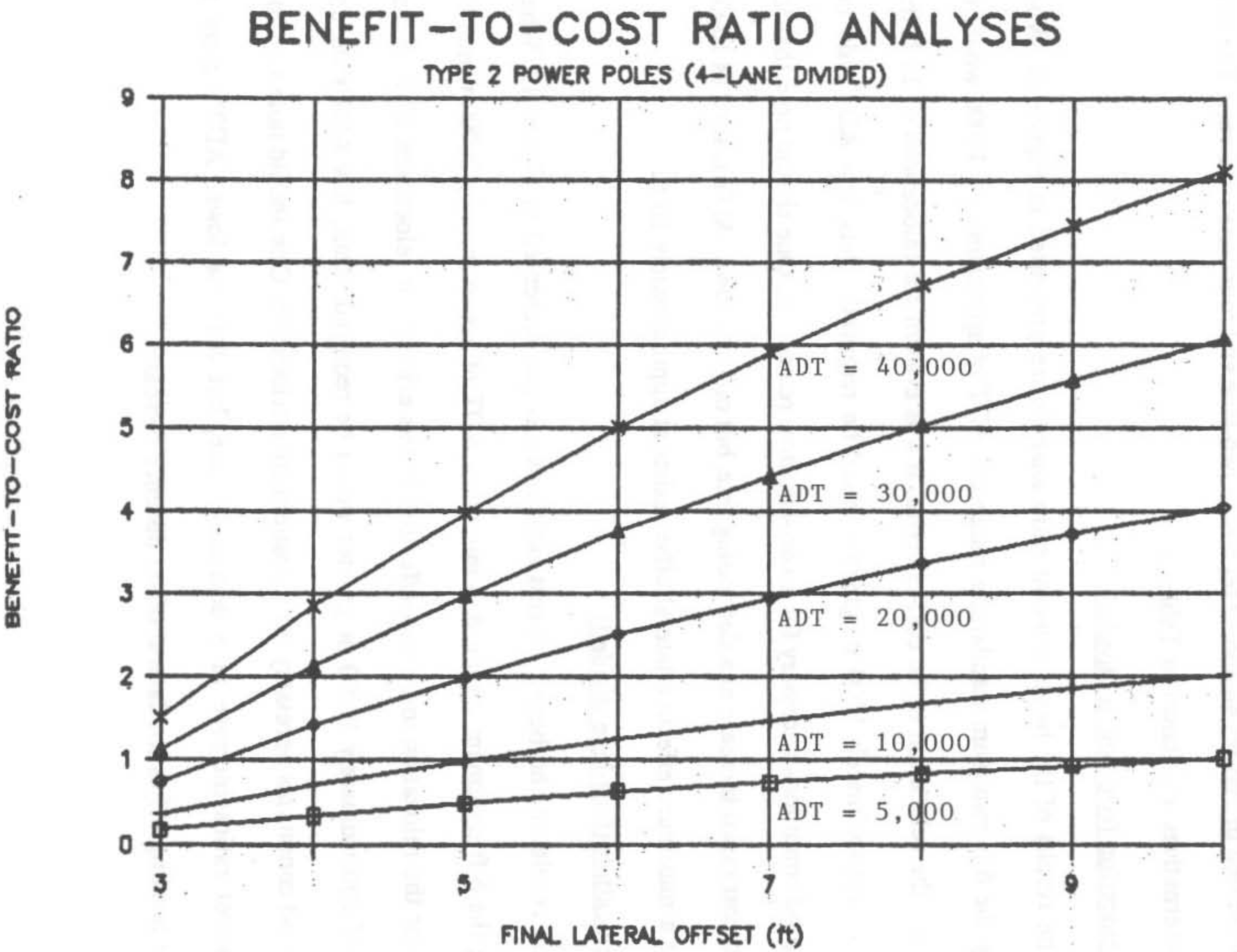


FIGURE 47. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 2 POWER POLES (4-LANE).

11.8 Type 3 Power Poles

The fourth utility installation which was analyzed was the Type 3 Power Pole. The results presented in Figures 48 and 49 represent two-lane and four-lane roadways. The costs for the alternatives are shown in Table 16.

11.8.1 Relocation (two-lane undivided)

The results of the benefit-to-cost ratio analysis are presented in Figure 48. When analyzing the 6 ft minimum standard, a minimum ADT of approximately 15000 would be required for the relocation to be cost-effective. It was evident for relocations of 10 ft that an ADT of approximately 9000 or greater would be required. Thus, low ADT's do not provide good conditions necessary for a cost-effective relocation. One should note that the benefit-to-cost ratios increase at a decreasing rate, but only the lower ADT's, such as 10000, show that a maximum effective lateral offset exists at approximately 10 ft.

11.8.2 Relocation (four-lane divided)

The results of the benefit-to-cost ratio analysis are presented in Figure 49. When analyzing the 6 ft minimum standard, a minimum ADT of approximately 20000 would be required for the relocation to be cost-effective. It was evident for relocations of 10 ft that an ADT of approximately 12000 or greater would be required. Thus, low ADT's do not provide good conditions necessary for a cost-effective relocation. One should note that the benefit-to-cost ratios increase at a decreasing rate, but only the lower ADT's show a significant leveling off as the lateral offset distance increases.

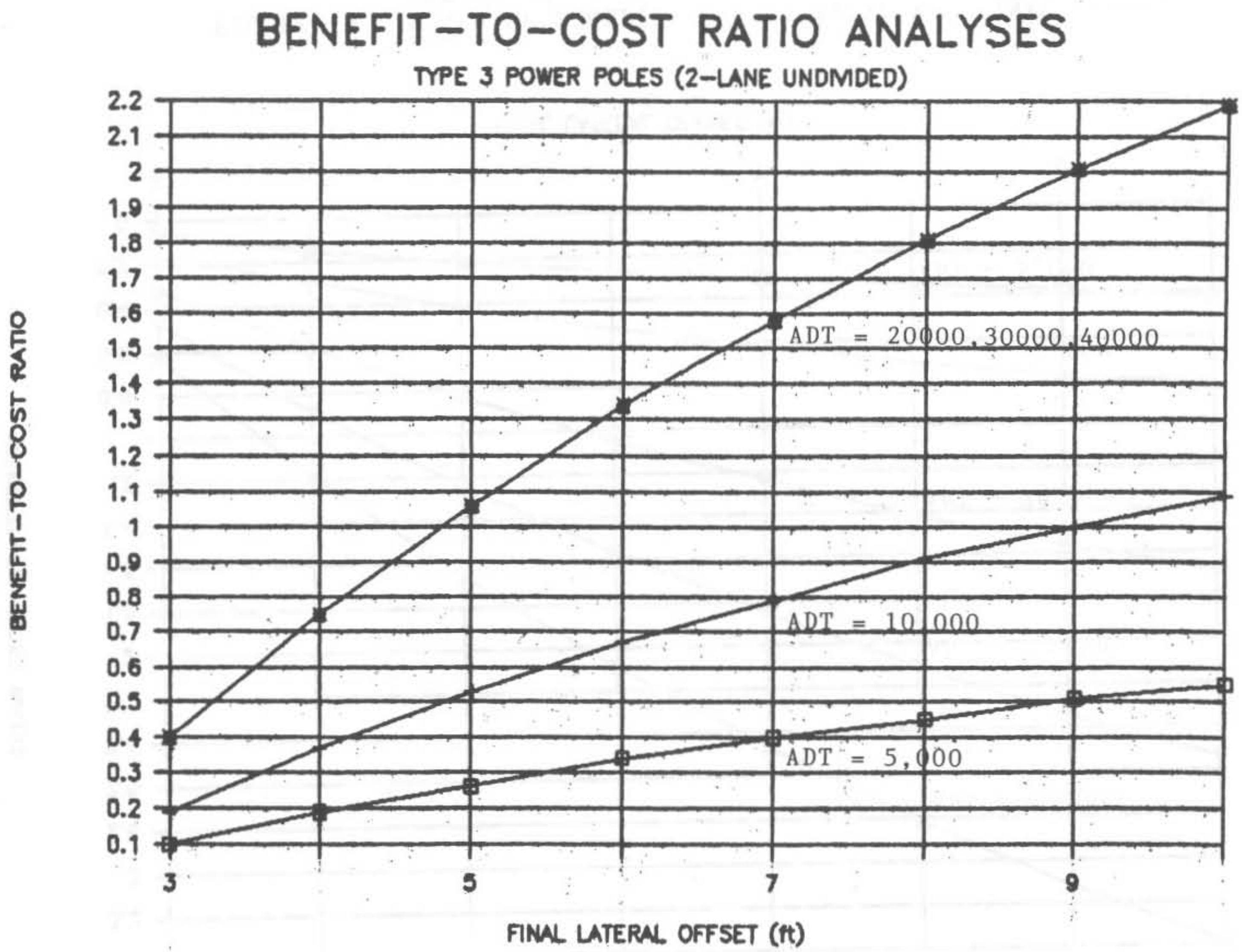


FIGURE 48. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 3 POWER POLES (2-LANE).

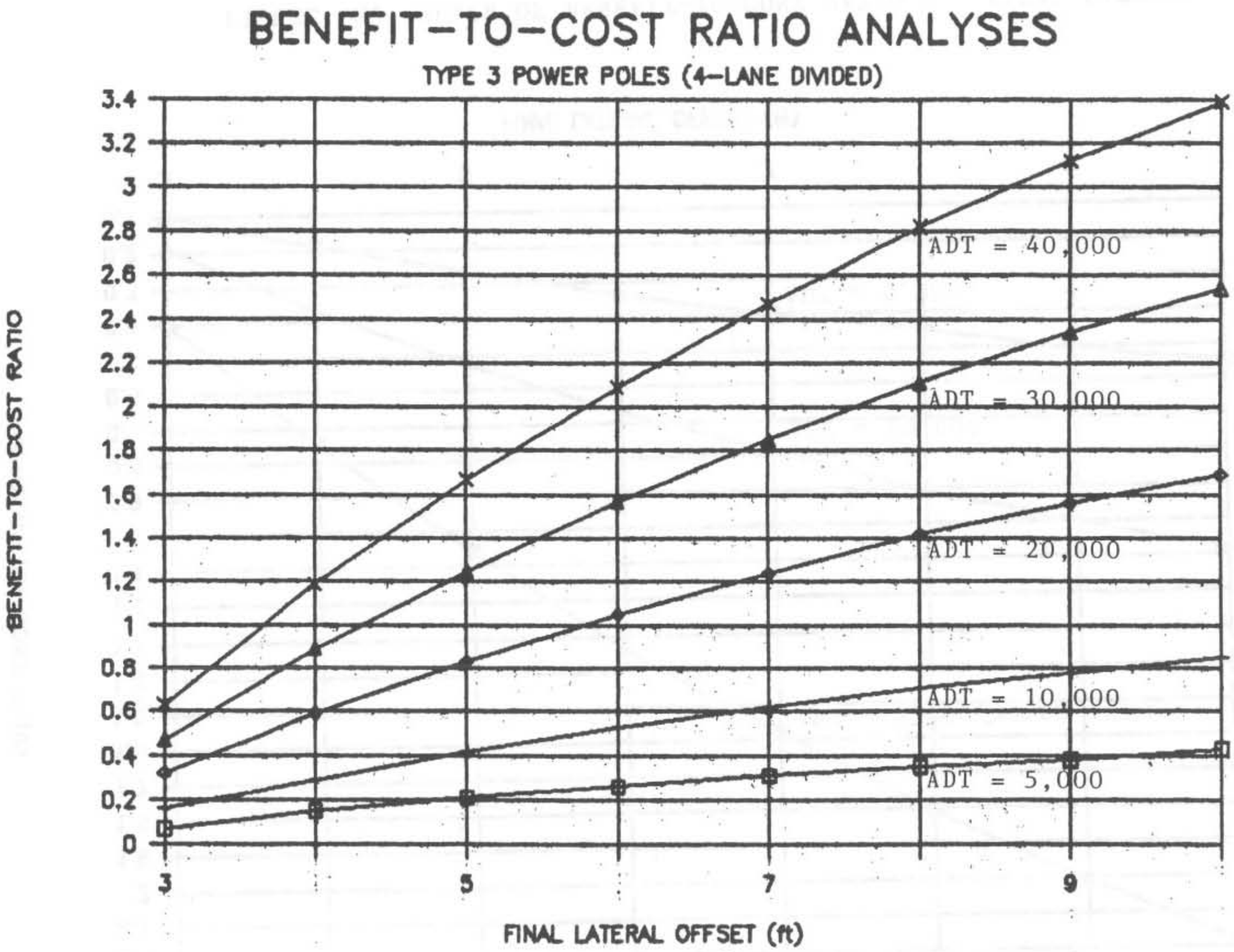


FIGURE 49. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 3 POWER POLES (4-LANE).

11.9 Type 4 Power Poles

The fifth utility installation which was analyzed was the Type 4 Power Pole. The results presented in Figures 50 and 51 represent two-lane and four-lane roadways. The costs for the alternatives are shown in Table 16.

11.9.1 Relocation (two-lane undivided)

The results of the benefit-to-cost ratio analysis are presented in Figure 50. When analyzing the 6 ft minimum standard, it would not be cost-effective to relocate the power pole for any of the ADT's (5000, 10000, 20000, 30000, or 40000). It was evident for relocations of 10 ft that an ADT of approximately 16000 or greater would be required. Once again, the low ADT's do not provide good conditions necessary for a cost-effective relocation. The benefit-to-cost ratios continue to increase at a decreasing rate.

11.9.2 Relocation (four-lane divided)

The results of the benefit-to-cost ratio analysis are presented in Figure 51. When analyzing the 6 ft minimum standard, a minimum ADT of approximately 34000 would be required for the relocation to be cost-effective. It was evident for relocations of 10 ft that an ADT of approximately 21000 or greater would be required. Thus, low ADT's do not provide good conditions necessary for a cost-effective relocation. The benefit-to-cost ratios continue to increase at a decreasing rate. The curves also show the benefit-to-cost ratios leveling off at approximately 10 ft.

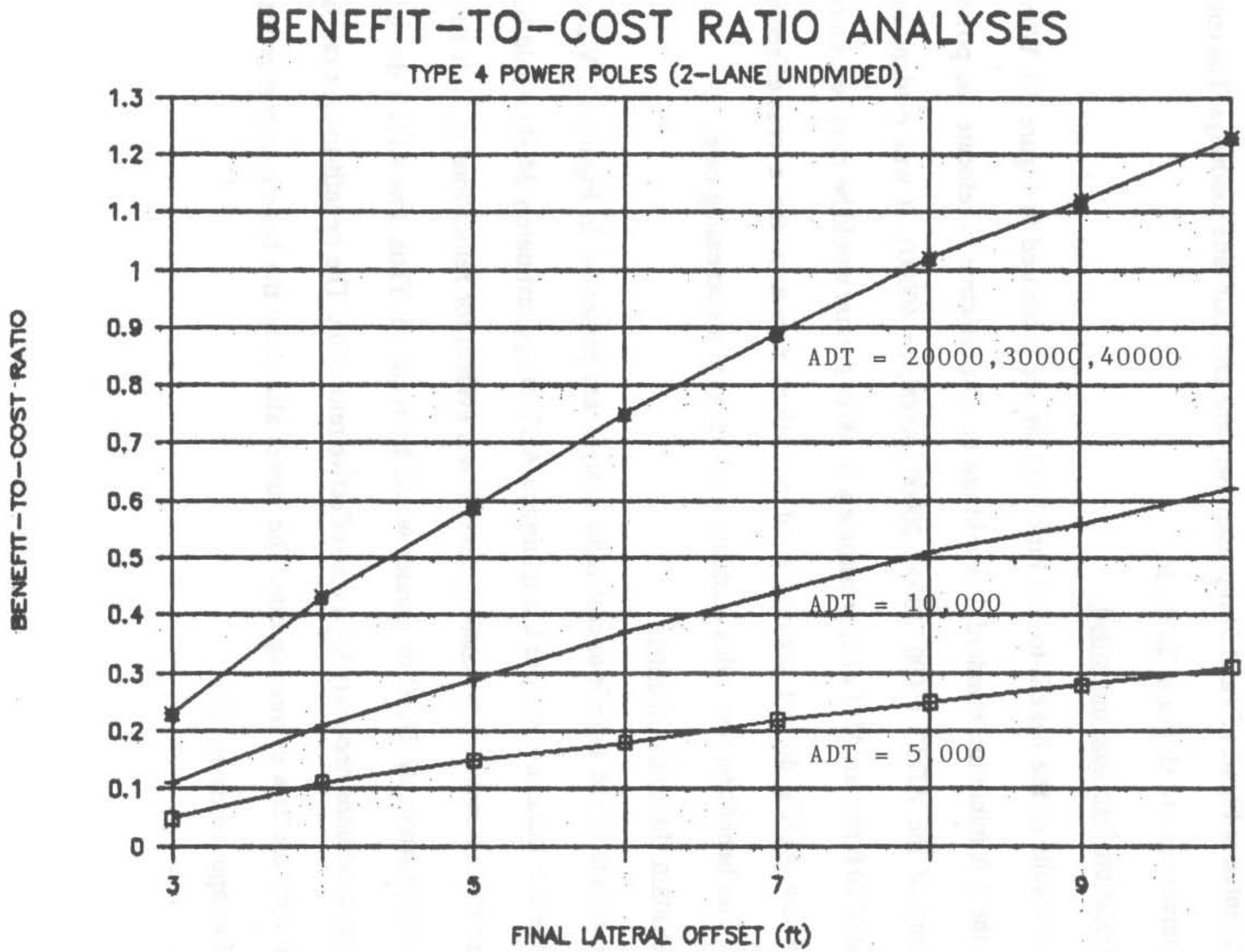


FIGURE 50. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 4 POWER POLES (2-LANE).

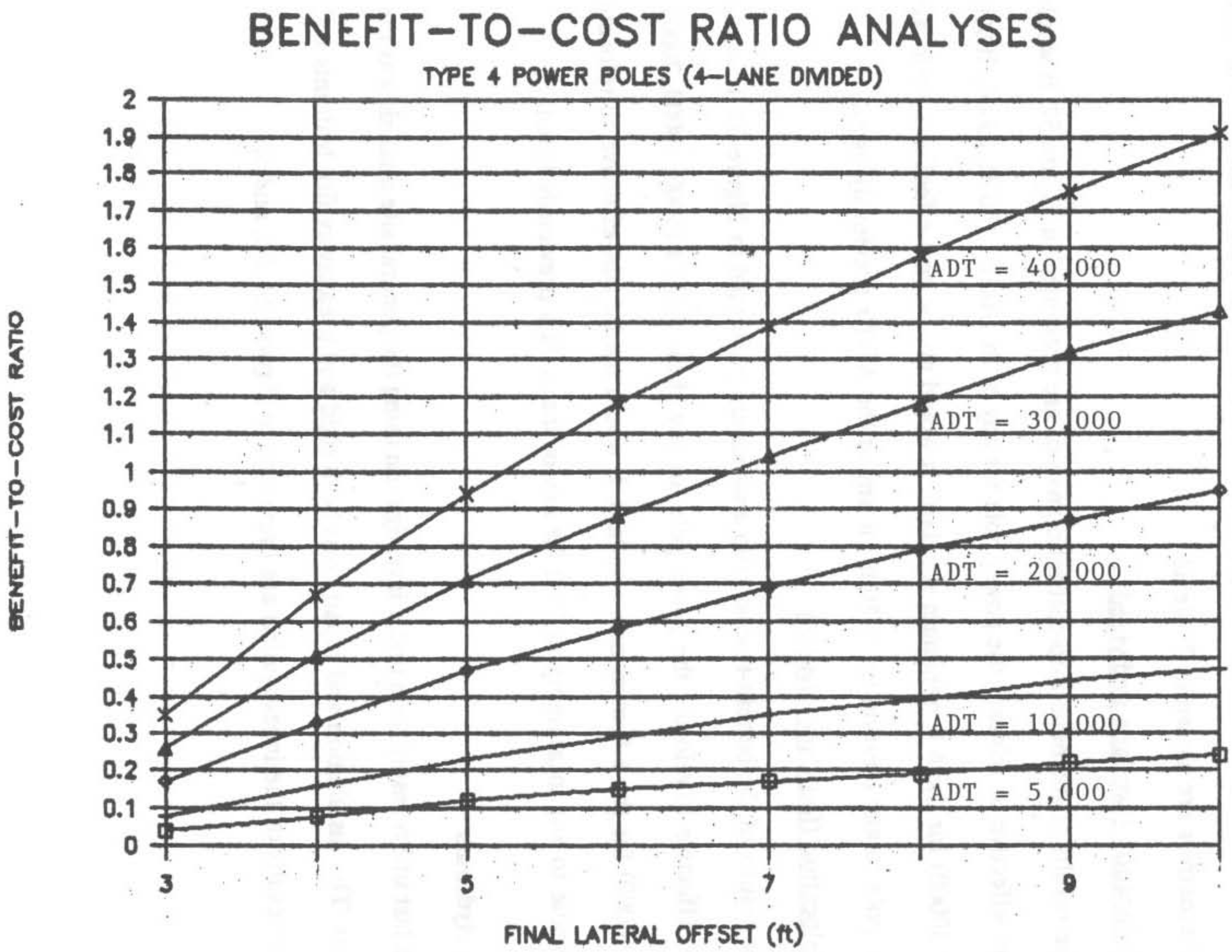


FIGURE 51. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 4 POWER POLES (4-LANE).

11.10 Type 5 Power Poles

The sixth and final utility pole installation analyzed was the Type 5 Power Pole. The results presented in Figures 52 and 53 represent two-lane and four-lane roadways. The costs for the alternatives are shown in Table 16.

11.10.1 Relocation (two-lane undivided)

The results of the benefit-to-cost ratio analysis are presented in Figure 52. It would not be cost-effective to relocate the power pole for any of the ADT's (5000, 10000, 20000, 30000, or 40000) for the 6 ft minimum standard. It would not be cost-effective to relocate the power pole to any location up to 10 ft for any of the ADT's previously listed.

11.10.2 Relocation (four-lane divided)

The results of the benefit-to-cost ratio analysis are presented in Figure 53. It would not be cost-effective to relocate the power pole for any of the ADT's (5000, 10000, 20000, 30000, or 40000) for the 6 ft minimum standard. It would not be cost-effective to relocate the power pole to any location up to 10 ft for any of the ADT's previously listed.

11.11 Fire Hydrants

The last utility installation under investigation using the general site analysis was the fire hydrants. The installation and repair costs both rigid and breakaway fire hydrants was $2,000. The results of the investigation are presented in Figures 54, 55, and 56.

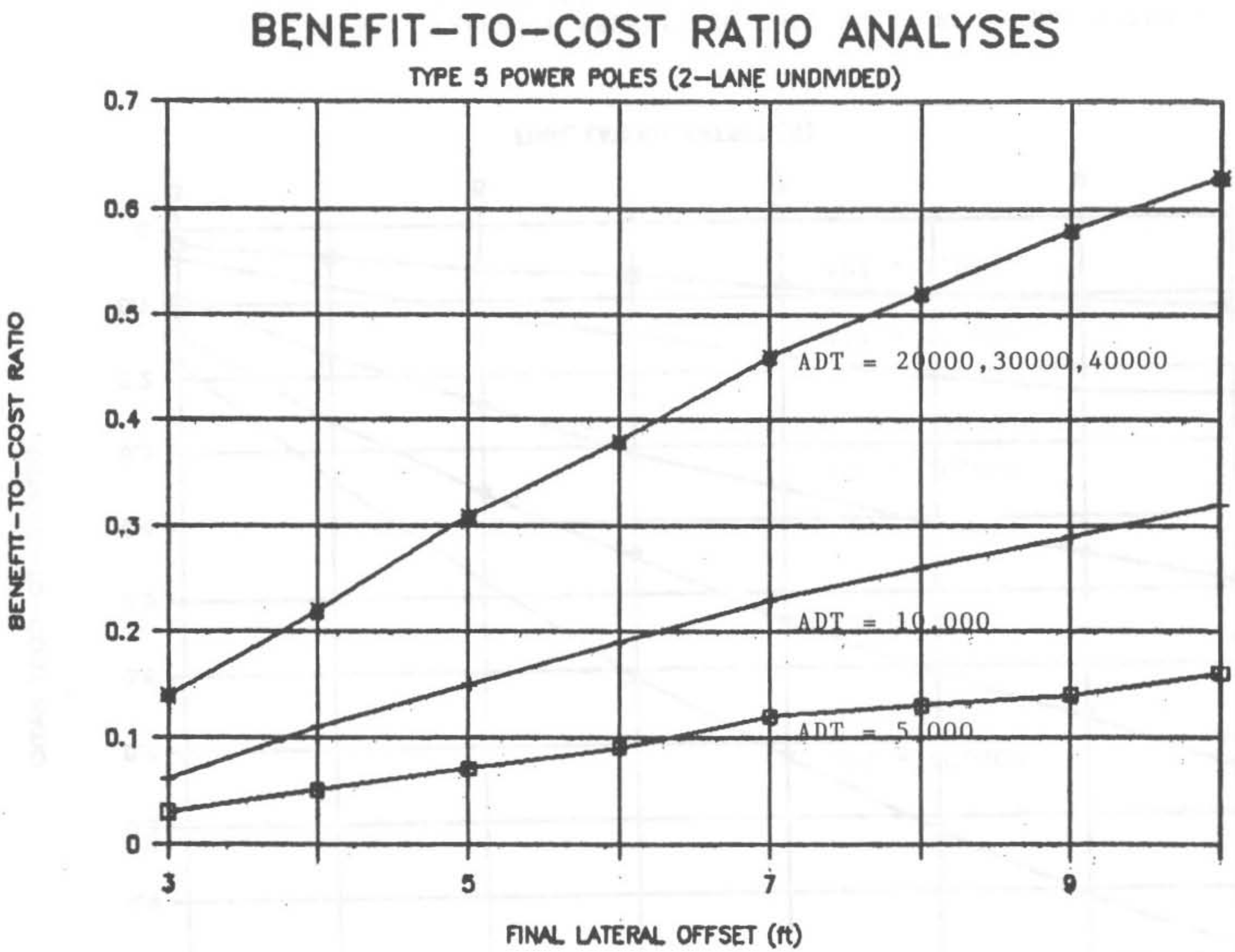


FIGURE 52. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 5 POWER POLES (2-LANE).

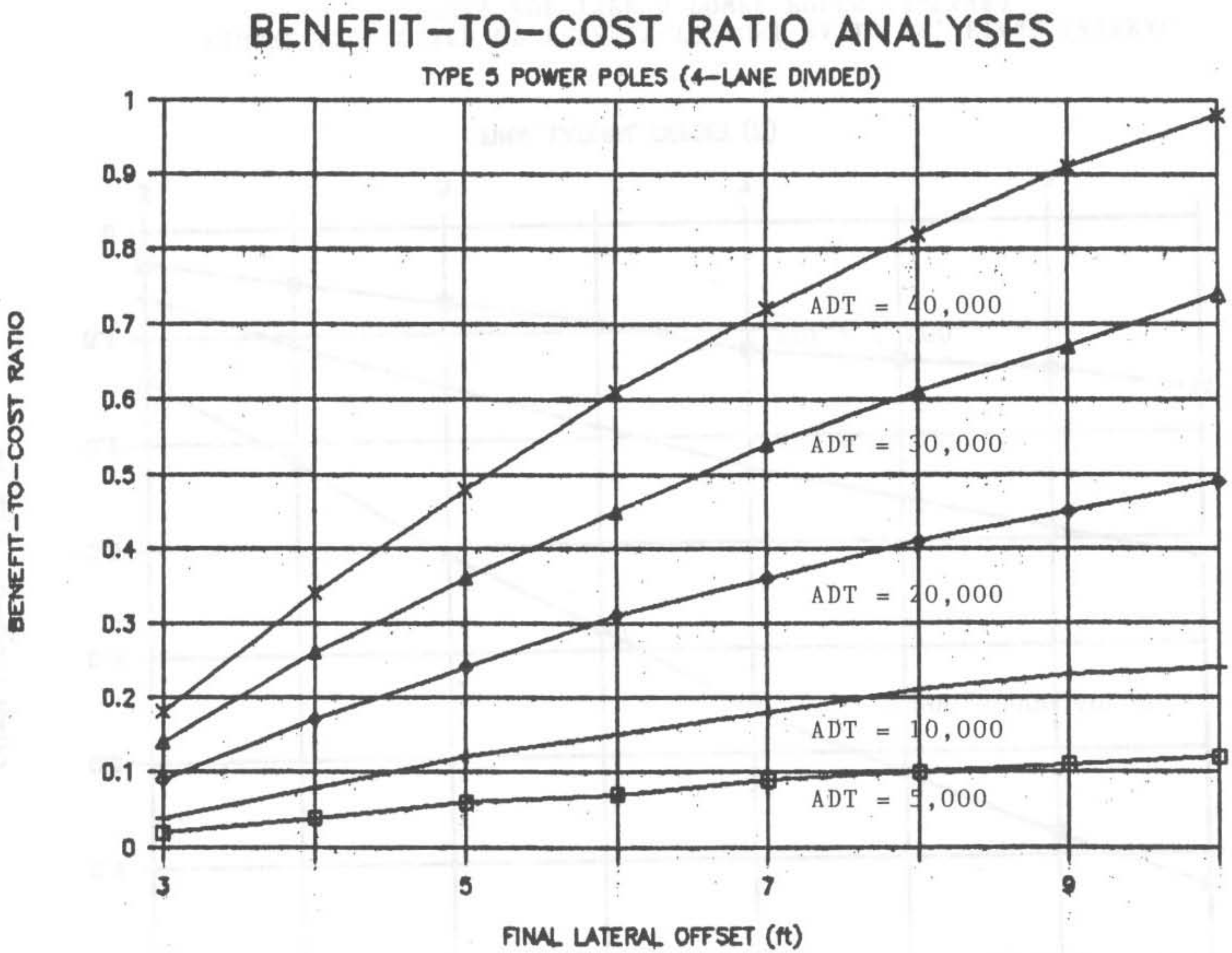


FIGURE 53. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR TYPE 5 POWER POLES (4-LANE).

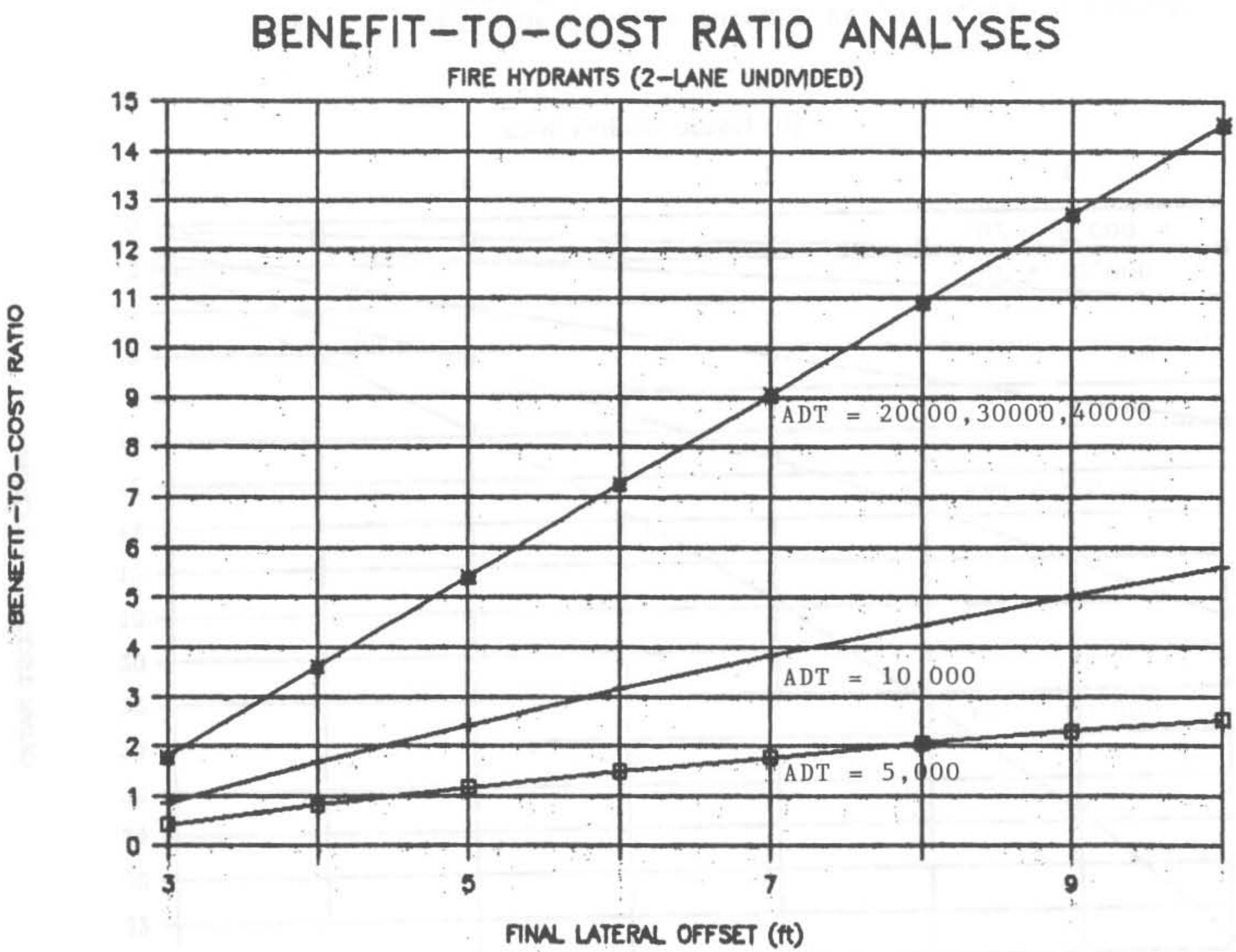


FIGURE 54. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR FIRE HYDRANTS (2-LANE),

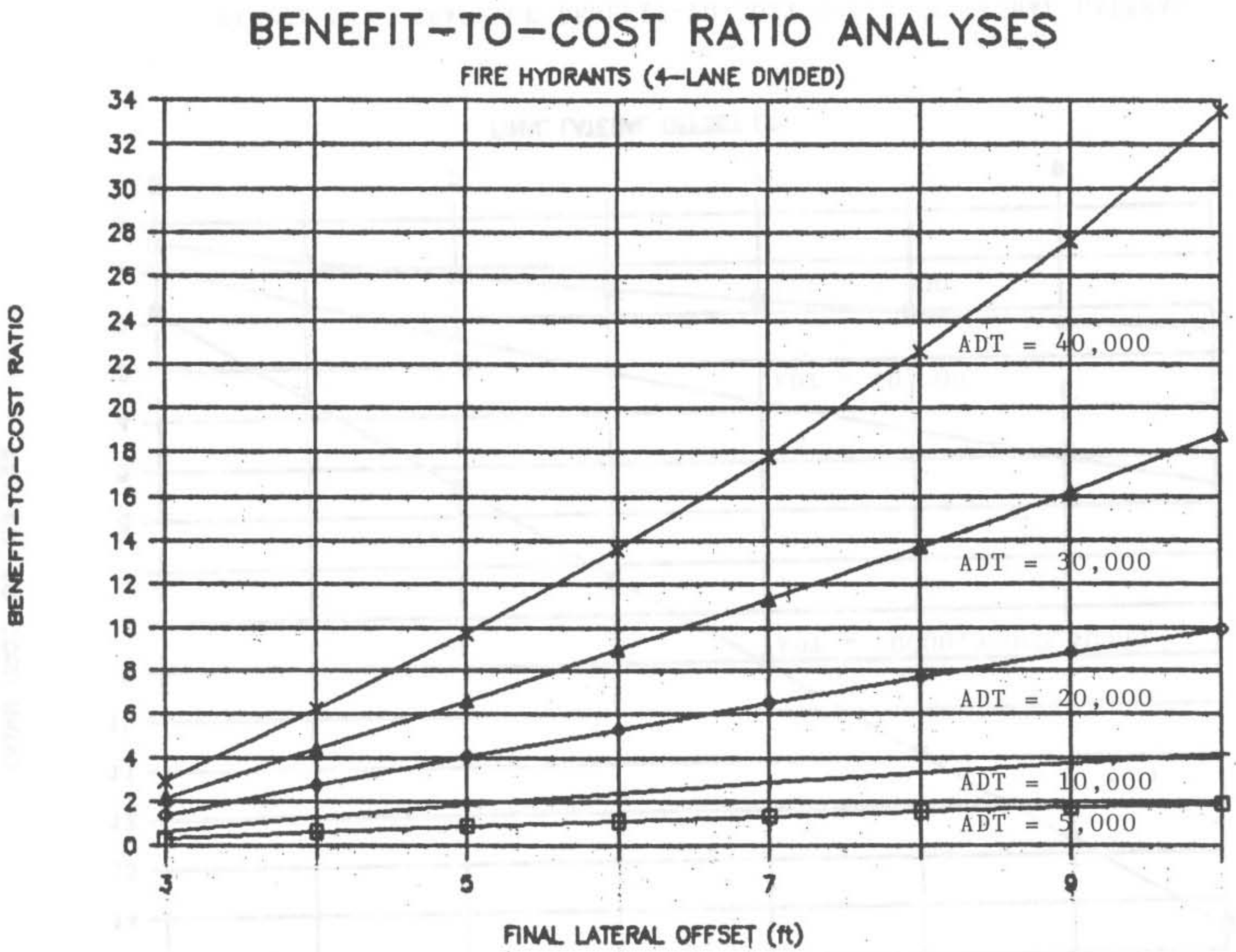


FIGURE 55. GRAPH OF BENEFIT-TO-COST RATIO VS. FINAL LATERAL OFFSET FOR FIRE HYDRANTS (4-LANE).

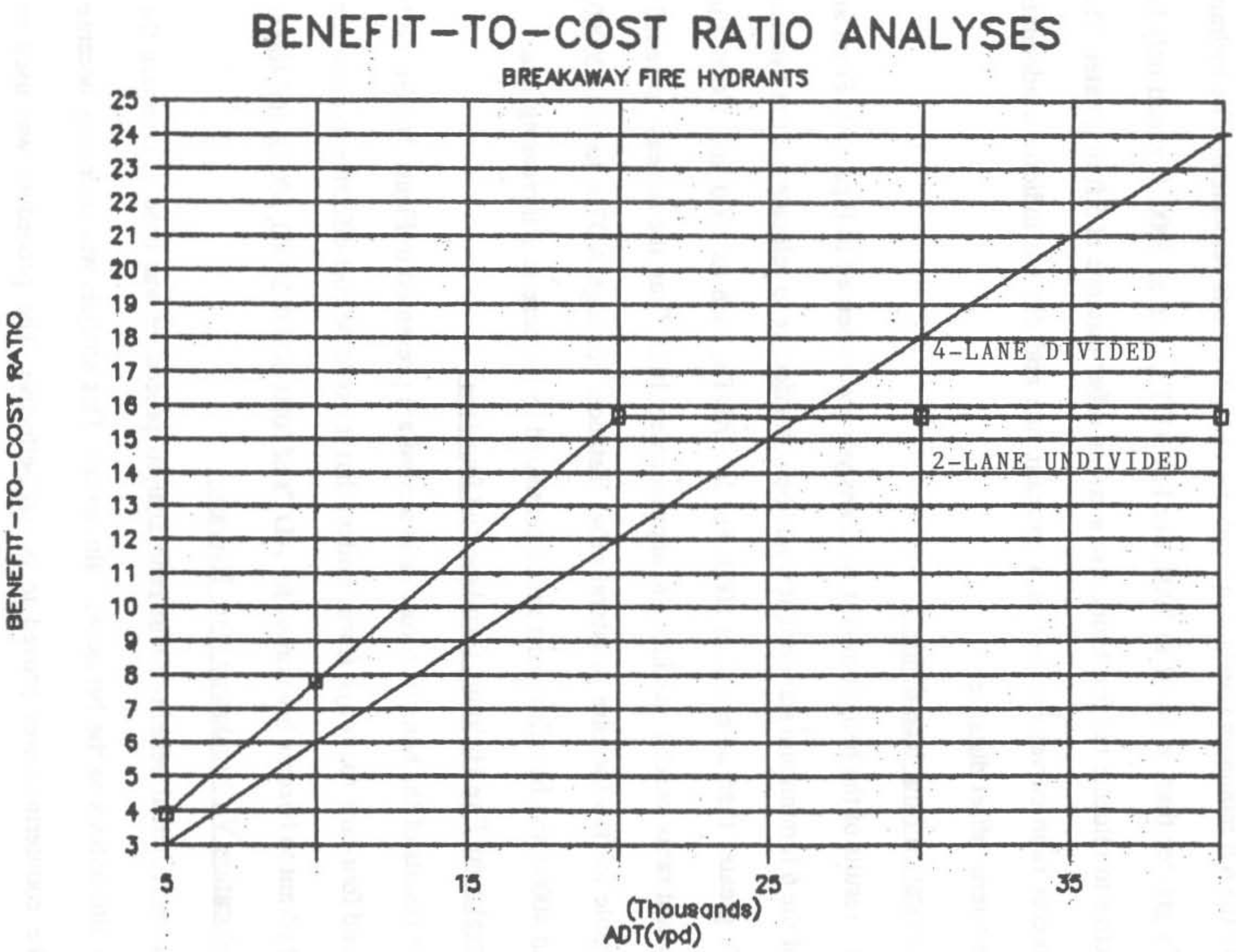


FIGURE 56. GRAPH OF BENEFIT-TO-COST RATIO FOR BREAKAWAY FIRE HYDRANTS.

11.11.1 Relocation (two-lane undivided)

The results of the benefit-to-cost ratio analysis are presented in Figure 54. From an analysis of the 6 ft minimum standard, it would be cost-effective to relocate the fire hydrant for ADT's greater than or equal to 3000. For low ADT's, such as 5000, it would only be cost-effective to relocate the fire hydrant to a lateral offset distance of 5 ft or greater. The benefit-to-cost ratio curves increase at a constant rate and did not indicate a adequate minimum lateral offset distance.

11.11.2 Relocation (four-lane divided)

The results of the benefit-to-cost ratio analysis are presented in Figure 55. From an analysis of the 6 ft minimum standard, it would be cost-effective to relocate the fire hydrant for ADT's greater than or equal to 5000. For low ADT's, such as 5000 and 10000, the benefit-to-cost ratios reach a maximum at approximately 10 ft. Thus, the increase in benefit was negligible for the increase in lateral offset distance. For high ADT's, such as 20000, 30000, and 40000, the benefit-to-cost ratios continued to increase at a increasing rate.

11.11.3 Breakaway Fire Hydrants (two-lane and four-lane)

The results of the benefit-to-cost ratio analysi are presented in Figure 56. For both two-lane and four-lane roadways, it was evident that it would be cost-effective to convert a rigid fire hydrant to become breakaway for ADT's of 5000, 10000, 20000, 30000, and 40000.

11.11.4 Relocation Vs. Breakaway (Fire Hydrants)

The incremental benefit-to-cost ratio analysis procedure was used to compare the relocation alternatives to the breakaway alternative. This analysis was necessary because both of the countermeasures proved to be cost-effective. The procedure was used to determine the location at which breakaway would be more cost-effective than relocation and vice versa. The comparison was performed using ADT's of 10000 and 40000 on a four-lane divided roadway. The analysis shown below indicates that it would be more cost-effective to convert the existing fire hydrants to a breakaway installation rather than to relocate an existing installation.

ADT = 10000 (4-lane, divided)

Countermeasure	EUAC	EUAB	B/C	Incremental B/C
1. 2 ft to 3 ft	199	134	0.67	
Breakaway @ 2 ft	204	1,227	6.02	218.6
2. 2 ft to 4 ft	194	253	1.31	
Breakaway @ 2 ft	204	1,227	6.02	97.4
3. 2 ft to 5 ft	190	354	1.86	
Breakaway @ 2 ft	204	1,227	6.02	62.4
4. 2 ft to 6 ft	186	446	2.39	
Breakaway @ 2 ft	204	1,227	6.02	43.4
5. 2 ft to 7 ft	182	526	2.89	
Breakaway @ 2 ft	204	1,227	6.02	31.9
6. 2 ft to 8 ft	180	598	3.32	
Breakaway @ 2 ft	204	1,227	6.02	26.2
7. 2 ft to 9 ft	177	663	3.74	
Breakaway @ 2 ft	204	1,227	6.02	20.9
8. 2 ft to 10 ft	174	721	4.14	
Breakaway @ 2 ft	204	1,227	6.02	16.9

ADT = 40000 (4-lane, divided)

Countermeasure	EUAC	EUAB	B/C	Incremental B/C
1. 2 ft to 3 ft	182	538	2.95	
Breakaway @ 2 ft	204	4,908	24.05	198.6
2. 2 ft to 4 ft	163	1,014	6.22	
Breakaway @ 2 ft	204	4,908	24.05	95.0
3. 2 ft to 5 ft	146	1,419	9.72	
Breakaway @ 2 ft	204	4,908	24.05	60.2
4. 2 ft to 6 ft	131	1,784	13.62	
Breakaway @ 2 ft	204	4,908	24.05	42.8
5. 2 ft to 7 ft	118	2,104	17.83	
Breakaway @ 2 ft	204	4,908	24.05	32.6
6. 2 ft to 8 ft	106	2,395	22.59	
Breakaway @ 2 ft	204	4,908	24.05	25.6
7. 2 ft to 9 ft	96	2,651	27.62	
Breakaway @ 2 ft	204	4,908	24.05	20.9
8. 2 ft to 10 ft	86	2,885	33.55	
Breakaway @ 2 ft	204	4,908	24.05	17.1

12 "ROADSIDE" SPECIFIC SITE ANALYSES

The one exception to the general site analysis approach was the analysis of the Wayne gas installation located in Wayne, Nebraska. The installation was located along the section of municipal highway at Site #2 which was analyzed in the multiple utility installation analysis using "UPACE".

The Wayne gas installation was used in this study, because it was an example of a single utility installation. The Nebraska Department of Roads (NDOR) requested that the safety improvement project implemented on the gas installation be analyzed from a cost-effectiveness point of view. The methodology used to evaluate the installation was the "ROADSIDE" computer model.

Before the safety improvement was implemented, the NDOR suggested various options which could be implemented. The suggested options, along with six other alternatives, were analyzed in a similar manner to the general site analysis.

One of the two options NDOR suggested was implemented in the field; the seven other alternatives and the actual safety improvements, were analyzed with a benefit-to-cost ratio analysis. The actual safety improvement and the other alternatives are described in the following section. The results of the analyses are also provided. Photographs of the original "before" and actual "final" installations are shown in Figure 57.

12.1 Wayne Gas Installation

12.1.1 Description of Countermeasures

The safety improvement options which were used in the evaluation process are as follows:

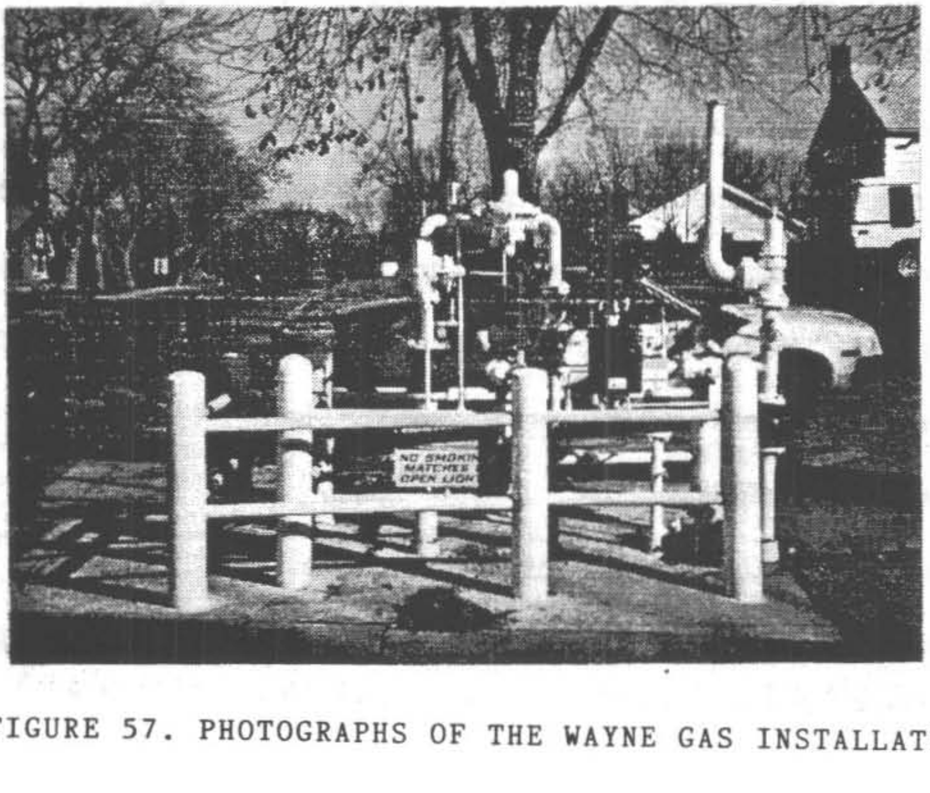


FIGURE 57. PHOTOGRAPHS OF THE WAYNE GAS INSTALLATION.

(1) Reinforcement of the existing barrier
(2) Construction of a new barrier using the 6 ft lateral offset
(3) Relocation of original gas installation to 7 ft offset
(4) Relocation of original gas installation to 8 ft offset
(5) Relocation of original gas installation to 9 ft offset
(6) Relocation of original gas installation to 10 ft offset
(7) Relocation of original gas installation to 30 ft offset
(8) Relocation of original gas installation to 50 ft offset

Options 1 and 2 were proposed by Peoples Natural Gas Company. The NDOR suggested that option 2 be implemented so that the 6 ft lateral offset distance could be maintained. Ultimately, option 1 was implemented in the field. These two options were viewed more feasible by Peoples Natural Gas Company due to the high costs necessary to remove and relocate the entire gas installation and barrier.

Options 3 through 6 were evaluated for comparison of relocating the installation to various increased lateral offsets. Options 7 and 8 were evaluated for the purpose of determining the effects of the gas installation being removed and relocated to a distant area.

12.1.2 "ROADSIDE" Computer Model Inputs

The first step of the analysis was to run the original case or do-nothing alternative in order to provide a base option against which to compare the new alternatives. The global values and the variable input values for this scenario are shown below:

	Global Values
Fatality	$1,500,000
Severe Personal Injury	$110,000
Moderate Personal Injury	$11,000
Slight Personal Injury	$3,000
Property Damage Only (Level 2)	$3,000
Property Damage Only (Level 1)	$500
Encroachment Rate (encroachments/mile/year/vpd)	0.00133
Encroachment Angle at 40 mph	17.2 degrees
Limiting Traffic Volume/Lane	10,000 vpd
Swath Width	12 feet

The variable data inputs that remain constant are as follows:

Traffic Volume	5,480
Roadway Type	Undivided, Two-Lane
Lane Width	15 feet
Roadway Curvature	0 degrees
Roadway Grade	0 degrees
User Adjustment Factor	1.0
Design Speed	40 mph
Hazard Offset From Curb	5 feet
Hazard Length	5 feet
Hazard Width	8 feet
Severity Index:	
Sides	3.8
Corners	3.8
Face	3.8
Project Life	20 years
Discount Rate	8%
Traffic Growth Rate (TGR)	2%
Salvage Value	$0

Only a small number of inputs were to be varied to analyze the eight countermeasures. The description of the roadside hazard (hazard offset distance, hazard length, and hazard width) and installation costs would change for the different countermeasures. The variable inputs are listed below:

Countermeasure	Offset Distance (ft)	Hazard Length (ft)	Hazard Width (ft)	Installation Cost ($)
1*	4*	7*	9*	4,268*
2	6	5	9	4,268
3	7	5	9	30,000
4	8	5	9	30,000
5	9	5	9	30,000
6	10	5	9	30,000
7	30	5	9	30,000
8	50	5	9	30,000

* - actual case implemented in the field

The costs for relocation and construction of the installations were obtained from Peoples Natural Gas Company. The dimensions of the existing safety improvement were obtained from a field site visit, while the original installation dimensions were obtained from the NDOR.

12.1.3 Results of the Computer Analyses

The option which showed the least desirable results was option 1, as shown in Figure 58. This option was implemented in the field. The negative results are not surprising, since the installation was moved closer to the roadway while at the same time the hazard size increased because of a larger protection barrier. This was why the benefit-to-cost ratio was calculated to be negative.

One benefit that was not considered in the analysis was the prevention of a possible hazardous situation due to an disastrous encroachment into the gas installation. The stronger system may be able to prevent an explosion or severe gas leak more than the original weaker system.

Option 2 was the relocation of the barrier to comply with the 6 ft minimum standard. It was evident that this option would not have been cost-effective. Option 3, 4, 5, and 6 also show to be poor alternatives from a cost-effectiveness perspective. They represent a relocation to a final lateral offset of 7 ft, 8 ft, 9 ft, and 10 ft, respectively.

Options 7 and 8 represent the relocation of the gas installation to 30 ft and 50 ft offsets, respectively. It was evident that both of these options produced benefit-to-cost ratios greater than 1.0.

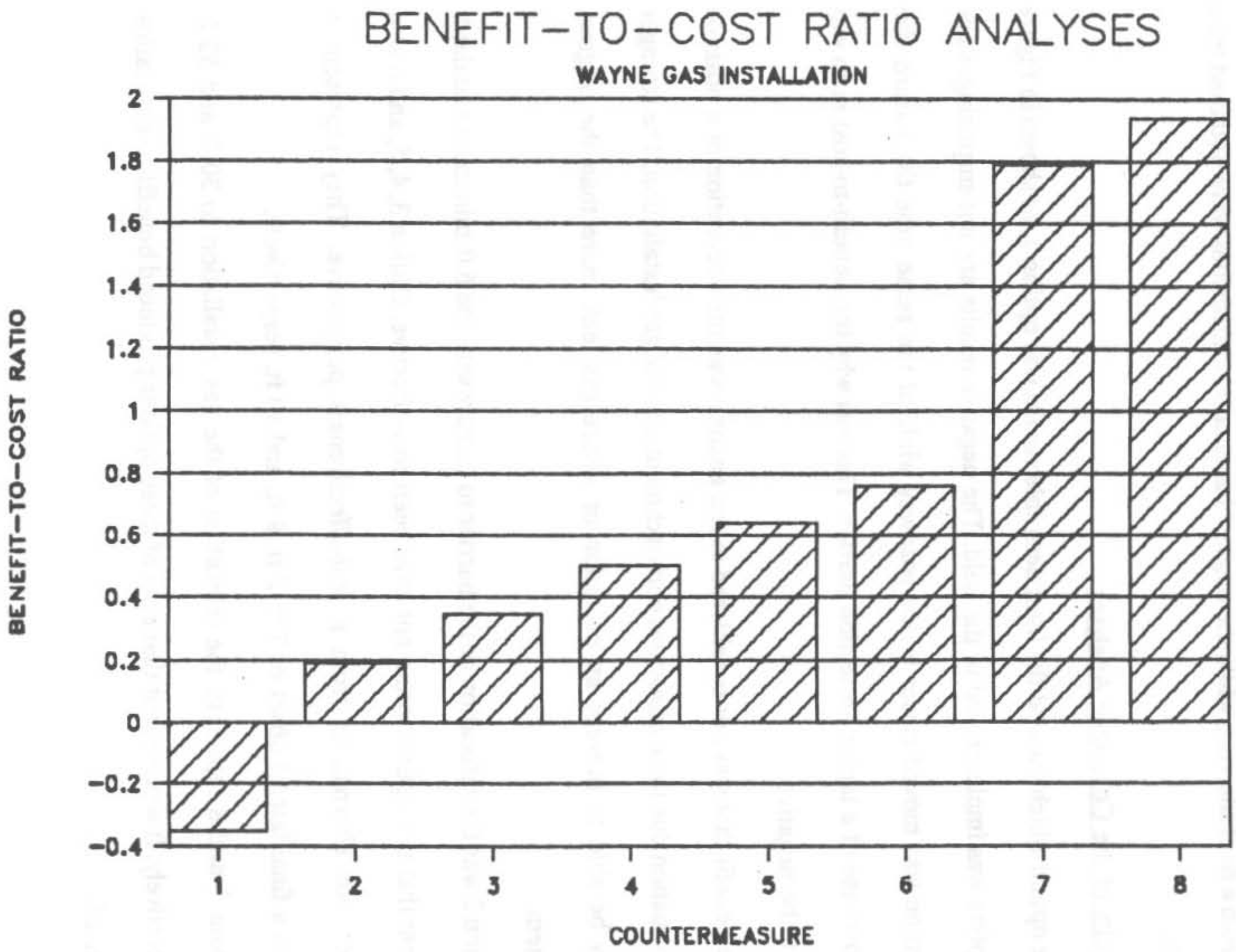


FIGURE 58. GRAPH OF BENEFIT-TO-COST RATIO VS. COUNTERMEASURE OPTION FOR THE WAYNE GAS INSTALLATION.

This may suggest that either one of these options would be desireble. However, the model did not consider the possibility of striking a fixed object, such as a house, when the gas installation would be relocated to some large lateral offset, i.e., in an alley or in the next block perpendicular from the roadway. Since moving the installation 30 ft or 50 ft from the roadway does not seem reasonable, a evaluation should be made using the logical alternatives. These included a relocation of the original appurtenance to a lateral offset between 6 ft and 10 ft at 1 ft increments.

When reviewing the 5 relocation alternatives (6 ft - 10 ft), the best alternative would be the relocation of the installation to 10 ft, even though the benefit-to-cost ratio is less than 1.0. Following the increasing trend shown in Figure 57, it was evident that at approximately 12 ft the benefit-to-cost ratio would be 1.0 or greater. Since the use of a breakaway type barrier would be very unrealistic in this situation, a relocation of any distance would be a safety improvement.

13 CONCLUSIONS AND RECOMMENDATIONS

It should be noted that the general site analyses were performed to reflect the possible safety improvements in an urban location in Nebraska. Three types of single utility installations, light poles, power poles, and fire hydrants, were analyzed to determine cost-effective safety improvements which consist of relocation or a breakaway conversion.

Many of the major computer inputs were based upon information supplied from various utility companies. This includes the typical locations (lateral offsets), relocation costs, maintenance costs, repair costs, and breakaway conversion costs.

The specific site analysis was performed to evaluate an actual case which was implemented in the field. It can be used as valuable resource information when making future decisions on safety improvements. If any information was gained from the site specific analysis, it was that it would be necessary to perform a cost-effectiveness analysis when considering improving such an installation.

The conclusions from the general site and specific site analyses could be used as a guide for determining whether a single utility countermeasure of the above mentioned installations should be implemented. The results provided information on cost-effective countermeasures, i.e., relocation and breakaway, to various types of single utility installations. If an actual project was seriously being considered for implementation, it would be recommended that actual field data be used in the computer analysis. It should be noted that there was no inclusion in the benefit-to-cost ratio analyses for the purchase of additional right-of-way.

14 REIMBURSEMENT POLICIES TO UTILITIES

14.1 Objective

The purpose of this task was to get a better understanding for other States' laws and policies covering reimbursement to utilities involved in highway construction. A reimbursement literature review is included for reference in Appendix P.

14.2 Scope

In order to obtain the reimbursement policies of other states, a letter was sent to each of the State Highway Departments requesting them to complete the questionnaire which accompanied the letter. A copy of the cover letter and questionnaire are included in Appendix Q.

14.3 Questionnaire Summary

The second questionnaire, referred to as QUESTIONNAIRE #2, was entitled, "UTILITY REIMBURSEMENT POLICY FOR HIGHWAY CONSTRUCTION LOCATIONS." The results of the responses for this questionnaire are presented in Table 18. A summary of the responses included in Table 18 are provided in Table 19 and Table 20. Fifty of 51 receipients responded to the questionnaire. A discussion of the questions and the States' responses to the questions is provided at this time. Please refer to Appendix Q for a review of the questions.

TABLE 18

Questionnaire #2 Responses

	AL	AK	AZ	AR	CA	CO	CT	DE	FL	GA	HI	ID	IL	IN	IA	KS	KY	LA
1. Is there a state reimbursement policy?	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2. Is the reimbursement policy set by: (1) State Law (2) Local Ordinances (3) Franchise Agreement (4) Other	-	(1)	(4)	(4)	(1)	(1)	(1)	(1,3)	(1)	(1)	(1)	(4)	(1)	(1)	(1)	(1)	(1)	(1)
3. Does the state use FHPM 6-6-3-1 to determine eligible costs?	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4. Are Federal Funds used for utility relocations?	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
a) Annual Percentage (1) >80% (2) 60-80% (3) 40-60% (4) 20-40% (5) <20%	-	(1)	(2)	(3)	(2)	(2)	(2)	(2)	(2)	(5)	(3)	(1)	(5)	(2)	(4)	(2)	(1)	(1)
b) Is cost a criteria for the use of federal funds?	-	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
(b)(1) If yes, at what cost range are federal funds pursued?	-	–	–	–	100,000	–	–	–	–	–	–	–	–	–	–	–	–	–
5. Does the state use alternate procedures as outlined in FHPM 6-6-3-1?	-	N	N	Y	Y	N	Y	N	Y	N	N	Y	Y	Y	N	Y	–	Y
6. Are utility relocation costs reimbursable to utilities for relocations required on public R.O.W.?	-	Y	Y	N	50/50	Y	Y	N	Y	N	Y	N	N	N	N	N	Y	N
7. Does your state issue permits to occupy public R.O.W.?	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
8. Does your state grant easements to utilities on public R.O.W.?	-	N	N	N	N	N	Y	N	N	N	N	N	N	N	N	N	N	N
9. Does your state grant franchise rights to utilities on public R.O.W.?	-	N	N	N	Y	N	Y	Y	N	N	Y	N	N	N	Y	N	N	N

	AL	AK	AZ	AR	CA	CO	CT	DE	FL	GA	HI	ID	IL	IN	IA	KS	KY	LA
10. Does your state charge a fee to provide the services described in questions 7, 8 or 9?	-	Y	N	N	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	N	N	N
11. Does the state's reimbursement policy differ for various types of utilities (i.e., electric power, telephone, pipeline or cable tv)?	-	N	N	N	Y	N	N	N	N	N	Y	N	N	N	N	N	Y	N
12. Does your state allow utilities to occupy your public R.O.W.?	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
13. Does your reimbursement policy vary for different roadway classifications?	-	N	Y	N	Y	N	Y	N	N	N	N	N	N	Y	-	N	Y	N
14. Has your state encountered an uncooperative utility (eg., refused to relocate facilities)?	-	N	N	Y	Y	N	N	N	N	N	N	N	N	Y	N	Y	N	Y
15. Is your state required to provide advance notice of projects to utilities?	-	Y	N	N	Y	N	N	N	Y	Y	N	N	N	Y	N	N	Y	Y
16. Does your state allow concurrent relocation construction by utilities during highway construction?	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y
17. Does your state have a <u>state-wide</u> 1-Call System for the location of utilities?	-	N	Y	Y	Y	Y	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	Y
18. Does your state require contractors to use the 1-Call System?	-	N	Y	N	N	Y	Y	Y	N	Y	N	N	Y	N	N	Y	N	Y
19. Does your state participate the 1-Call System?	-	N	N	N	N	N	Y	Y	N	N	N	N	N	N	N	Y	N	Y

	ME	MD	MA	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY	NC	ND	OH
1. Is there a state reimbursement policy?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2. Is the reimbursement policy set by: (1) State Law (2) Local Ordinances (3) Franchise Agreement (4) Other	(1)	(1)	(1)	(1)	(1)	(1)	(1,4)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
3. Does the state use FHPM 6-6-3-1 to determine eligible costs?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
4. Are Federal Funds used for utility relocations?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
a) Annual Percentage (1) >80% (2) 60-80% (3) 40-60% (4) 20-40% (5) <20%	(1)	(4)	(1)	(1)	(2)	(5)	(3)	(2)	(4)	(2)	(1)	(1)	(3)	(2)	(2)	(1)	(2)
b) Is cost a criteria for the use of federal funds?	N	Y	N	N	N	N	Y	N	Y	N	N	N	N	N	N	N	N
(b)(1) If yes, at what cost range are federal funds pursued?	–	100,000	–	–	–	–	50,000	–	100,000	–	–	–	–	–	–	–	–
5. Does the state use alternate procedures as outlined in FHPM 6-6-3-1?	N	Y	N	–	N	N	Y	N	N	Y	N	Y	Y	Y	Y	Y	Y
6. Are utility relocation costs reimbursable to utilities for relocations required on public R.O.W.?	50/50	N	Y	N	N	N	N	Y	N	Y	50/50	Y	N	N	N	N	N
7. Does your state issue permits to occupy public R.O.W.?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
8. Does your state grant easements to utilities on public R.O.W.?	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N	N	N	N
9. Does your state grant franchise rights to utilities on public R.O.W.?	Y	N	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N
10. Does your state charge a fee to provide the services described in questions 7, 8 or 9?	N	N	N	Y	N	N	N	N	N	Y	N	Y	N	Y	N	Y	N
11. Does the state's reimbursement policy differ for various types of utilities (i.e., electric power, telephone, pipeline or cable tv)?	N	N	N	N	N	N	N	N	N	N	Y	N	N	N	N	N	N
12. Does your state allow utilities to occupy your public R.O.W.?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
13. Does your reimbursement policy vary for different roadway classifications?	Y	Y	Y	N	Y	N	N	N	N	N	Y	N	Y	Y	N	N	N

	ME	MD	MA	MI	MN	MS	MO	MT	NE	NV	NH	NJ	NM	NY	NC	ND	OH
14. Has your state encountered an uncooperative utility (eg., refused to relocate facilities)?	N	Y	N	N	N	N	N	N	Y	N	N	N	Y	Y	Y	N	N
15. Is your state required to provide advance notice of projects to utilities?	Y	N	N	Y	N	N	N	Y	N	N	N	N	Y	Y	Y	Y	Y
16. Does your state allow concurrent relocation construction by utilities during highway construction?	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
17. Does your state have a <u>state-wide</u> 1-Call System for the location of utilities?	N	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	Y	Y	N	Y
18. Does your state require contractors to use the 1-Call System?	N	Y	Y	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	Y	N	Y
19. Does your state participate in the 1-Call System?	N	N	Y	N	Y	N	N	N	N	N	N	Y	N	Y	Y	N	N

	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI	WY	PR
1. Is there a state reimbursement policy?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
2. Is the reimbursement policy set by: (1) State Law (2) Local Ordinances (3) Franchise Agreement (4) Other	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)	(1)
3. Does the state use FHPM 6-6-3-1 to determine eligible costs?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	50/50	Y
4. Are Federal Funds used for utility relocations?	Y	Y	Y	Y	Y	50/50	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
a) Annual Percentage (1) >80% (2) 60-80% (3) 40-60% (4) 20-40% (5) <20%	(3)	(2)	(3)	(5)	(2)	(5)	(2)	(4)	(1)	(5)	(4)	(5)	(1)	(5)	(5)	(2)
b) Is cost a criteria for the use of federal funds?	Y	N	N	N	N	N	N	N	N	N	Y	N	N	N	Y	N
(b)(1) If yes, at what cost range are federal funds pursued?	500,000	–	–	–	–	–	–	–	–	–	25,000	–	–	–	500,000	–
5. Does the state use alternate procedures as outlined in FHPM 6-6-3-1?	Y	N	Y	–	N	N	N	Y	N	N	N	N	Y	N	N	Y
6. Are utility relocation costs reimbursable to utilities for relocations required on public R.O.W.?	N	N	N	Y	N	N	–	Y	Y	N	N	N	50/50	N	50/50	Y
7. Does your state issue permits to occupy public R.O.W.?	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
8. Does your state grant easements to utilities on public R.O.W.?	N	N	N	Y	Y	Y	N	N	Y	N	N	Y	N	N	50/50	N
9. Does your state grant franchise rights to utilities on public R.O.W.?	N	N	N	N	N	–	N	N	Y	N	N	Y	N	N	N	Y
10. Does your state charge a fee to provide the services described in questions 7, 8 or 9?	Y	N	Y	Y	N	N	N	N	Y	N	Y	Y	N	N	N	N
11. Does the state's reimbursement policy differ for various types of utilities (i.e., electric power, telephone, pipeline or cable tv)?	N	N	N	N	N	N	N	N	Y	N	Y	N	Y	N	50/50	Y
12. Does your state allow utilities to occupy your public R.O.W.?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
13. Does your reimbursement policy policy vary for different roadway classifications?	Y	N	N	N	N	N	Y	Y	Y	Y	Y	N	Y	N	Y	N

	OK	OR	PA	RI	SC	SD	TN	TX	UT	VT	VA	WA	WV	WI	WY	PR
14. Has your state encountered an uncooperative utility (eg., refused to relocate facilities)?	N	N	Y	Y	N	N	Y	Y	N	N	N	N	N	N	Y	Y
15. Is your state required to provide advance notice of projects to utilities?	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	N	N	Y	50/50	Y
16. Does your state allow concurrent relocation construction by utilities during highway construction?	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
17. Does your state have a <u>state-wide</u> 1-Call System for the location of utilities?	Y	Y	Y	–	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	N
18. Does your state require contractors to use the 1-Call System?	N	Y	Y	–	N	N	Y	N	Y	Y	Y	Y	N	N	50/50	N
19. Does your state participate in the 1-Call System?	Y	Y	Y	–	N	N	Y	N	Y	Y	N	Y	N	N	Y	N

TABLE 19

Summary of Questionnaire #2 Responses

QUESTION NO.	RESPONSES				
	YES	NO	SUBTOTAL	BLANK	TOTAL
1	50(100%)	0(0%)	50	0	50
2[1]	---	---	---	---	---
3	49.5(99%)	0.5(1%)	50	0	50
4	49.5(99%)	0.5(1%)	50	0	50
4(a)[1]	---	---	---	---	---
4(b)	7(14%)	43(86%)	50	0	50
4(b)(1)[1]	---	---	---	---	---
5	23(48.9%)	24(51.1%)	47	3	50
6	17.5(35.7%)	31.5(64.3%)	49	1	50
7	49(98%)	1(2%)	50	0	50
8	8.5(17%)	41.5(83%)	50	0	50
9	10(20.4%)	39(79.6%)	49	1	50
10	20(40%)	30(60%)	50	0	50
11	8.5(17%)	41.5(83%)	50	0	50
12	50(0%)	0(0%)	50	0	50
13	20(40.8%)	29(59.2%)	49	1	50
14	16(32%)	34(68%)	50	0	50
15	24.5(49%)	25.5(51%)	50	0	50
16	46(92%)	4(8%)	50	0	50
17	35(71.4%)	14(28.6%)	49	1	50
18	26.5(54.1%)	22.5(45.9%)	49	1	50
19	17(34.7%)	32(65.3%)	49	1	50

[1] - see Table 20

TABLE 20

Summary of Questionnaire #2 Responses (Continued)

QUESTION NO.	RESPONSES
2	State Law 47 Local Ordinance 0 Franchise Agreement 1 Other 4 (Case Law, Court Ruling and Administrative Rule, Federal Requirements, Highway Commission)
4(a)	<20% 9 (18%) 20-40% 5 (10%) 40-60% 6 (12%) 60-80% 18 (36%) >80% 12 (24%)
4(b)(1)	$500,000 2 states $100,000 3 states $50,000 1 state $25,000 1 state Average Cost Range = $196,429

Question #1:

The purpose of this question was to determine how many states currently have a policy for reimbursement of relocation costs to utilities during highway construction. Of the 50 states which responded to this question, all 50 (100%) states replied that they currently have a specific reimbursement policy as given in Table 19.

Question #2:

This question was asked to determine how these reimbursement policies were developed and enforced. The questionnaire provided the following choices: (1) State Law, (2) Local Ordinance, or (3) Franchise Agreement. Of the 50 returned questionnaires, State Law was checked by 47 states, Local Ordinance by no states, Franchise Agreement by 1 state, and 4 states listed some other reason. These answers are presented in Table 20 next to "Other."

Question #3:

This question sought to determine how many states follow the FHWA policy which is included in the Federal-Aid Highway Program Manual (FHPM) 6-6-3-1 for determining eligible costs. From Table 19, it was evident that 49.5 (99%) of the 50 states which responded to the question use FHWA policy in FHPM 6-6-3-1. A copy of this policy was included in Appendix R.

Question #4:

This question was asked for the purpose of verifying whether other states use Federal Funds for utility relocations. From Table 19, it was shown that all 50 (100%) of the states which responded to the questionnaire use Federal Funds.

Question #4(a):

Each state was asked to specify the approximate percentage of reimbursable utility costs for which their state uses Federal Funds. From Table 20, it was evident that the majority of the states use Federal Funds for reimbursable utility costs. That is, 30 (60%) of the 50 states which responded use Federal Funds on over 60% of the annual reimbursable utility costs, and 12 (24%) of the 50 states which responded use Federal Funds on over 80% of the annual reimbursable utility costs.

Question #4(b):

Each state was then asked to state whether cost was a criteria for requesting the use of Federal Funds. From Table 19, only 7 (14%) of the 50 states which responded use cost as a criteria for obtaining Federal Funds.

Question #4(b)(1):

This question was asked to determine what dollar amount states set when cost was a criteria used for pursuing Federal Funds. From Table 20, it was evident that a large range of responses, varying from $25,000 to $500,000, were given. The average cost range was $196,429 from the responses of the 7 states which responded "YES" to question #4(b).

Question #5:

This question was included for the purpose of determining how many states use the alternate procedures in FHPM 6-6-3-1 which simplify the processing of utility relocations or adjustments. From Table 19, the responses were evenly distributed with 23 (48.9%) of the 47 states which responded use the alternate procedures, while 24 (51.1%) of the 45 states do not use the alternate procedures.

Under the alternate procedure, the State Highway Agency (SHA) is to act in the relative position of the FHWA Division Administrator for reviewing and approving the arrangement, fees, estimates, plans, agreements, and other related matters required by this directive as prerequisites for authorizing the utility to proceed with and complete the work.

Question #6:

This question was asked to determine how many states reimburse utilities for relocation costs when the utility facilities are located on public right-of-way. From Table 19, it was found that 17.5 (35.7%) of the 49 states which responded reimburse utilities located on public right-of-way.

In the absence of statute, the courts have consistently held that a utility must pay the costs of relocation when they are required to relocate their facilities while on public right-of-way due to highway construction or improvements.

Question #7:

This question, along with questions #8 and #9, was asked to determine by what means a state allows a utility to locate it facilities in public right-of-way. The method addressed by this question was through the issuing of a permit. From Table 19, it was evident that 49 (98%) of the 50 states issue permits to utilities.

Question #8:

This question, related to questions #7 and #9, asked whether a state grants easements to utilities on public right-of-way. From Table 19, it was evident that only 8.5 (17%) of the 50 states grant easements to utilities.

An "easement" is defined as an interest in land owned by another that entitles its holder to a specific limited use or enjoyment. It is also referred to as private right-of-way. The courts have consistently held that where the utility's facilities are located on private property, the highway agency may not compel them to be relocated without paying just compensation.

Question #9:

This question, related to questions #7 and #8, asked whether a state grants franchise rights to utilities on public right-of-way. From Table 19, it was evident that only 10 (20.4%) of the 49 states grant franchise rights to utilities. A "franchise" is defined as a special privilege conferred by a state on an individual or corporation to do that which a citizen cannot do by common right. A franchise usually does not create an interest in the land; although, it requires the occupancy of land.

Question #10:

This question was asked to determine if a state charges a fee to provide the services described in questions #7, #8, and #9. From Table 19, only 20 (40%) of the 50 states stated they charge a fee. Of the states that charge a fee, many responded that it was a minimal fee for handling and processing the paperwork.

Question #11:

This question asked whether a state's reimbursement policy differed for various types of utilities (i.e. electric power, telephone, pipeline, or cable tv). From Table 19, it was evident that only 8.5 (17%) of the 50 states had differences in their policies. As stated in the reimbursement policy literature review by Thomas (45), a government may not discriminate unfairly among utilities, and any distinction between utilities involving relocation cost or reimbursement must have a reasonable, rational basis.

Question #12:

This question asked whether a state allows a utility to occupy public right-of-way. As given in Table 19, all 50 (100%) of the states which responded allow the utilities to occupy public right-of-way.

Question #13:

This question was asked to determine whether a state's reimbursement policy varies for different roadway classifications. From Table 19, it was evident that 20 (40.8%) of the 49 states which responded to the question have differences in the reimbursement policy for specific roadway classifications.

Question #14:

Each state was asked whether their state had ever encountered an uncooperative utility (e.g. which refused to relocate). From Table 19, there were 16 (32%) of the 50 states which indicated they had encountered an uncooperative utility.

Question #15:

This question asked each state whether they were required to provide advance notice of highway construction or improvement projects to utilities. From Table 19, only 24.5 (49%) of the 50 states indicated they are required to provide advance notification. Although less than 50% of the states are required to provide advance notice to utilities, many of the other states indicated that they do provide advance notice of projects because it is just good policy to do so.

Question #16:

This question was asked to determine if states allow the utilities to relocate their facilities while the highway construction or improvement project was taking place. As given in Table 19, 46 (92%) of the 50 states indicated they allow concurrent utility relocation and highway construction or improvements.

Question #17:

Each state was then asked whether their state had a state-wide 1-Call system for the location of utilities. From Table 19, 35 (71.4%) of the 49 states indicated they currently have such a system. It should be noted that, although only 35 states have a state-wide system, other states may have a 1-Call system even though it isn't state-wide.

A 1-Call system is usually provided by a private company which offers their service for a fee. When a call is placed to this company, they will come to the site in question and inform the caller of all the currently placed utilities in the area. Both utilities and the state can participate in the system by paying the fee.

<u>Question #18:</u>

This question asked whether each state requires contractors to use the 1-Call system. As given in Table 19, 26.5 (54.1%) of the 49 states require contractors to use it.

<u>Question #19:</u>

The final question was directed toward each state's participation in the 1-Call system. Each state was asked whether they participate in it and subsequently support it financially. In Table 19, only 17 (34.7%) of the 49 states participate in the 1-Call system.

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16 APPENDICES

APPENDIX A

LATERALOBSTACLE CLEAR ZONE POLICIES FOR FIXED OBJECTS LOCATED ON MUNICIPAL STREETS (QUESTIONNAIRE #1)

June 13, 1989

The University of Nebraska-Lincoln is currently conducting a research study for the Nebraska Department of Roads (NDOR), entitled "Economic and Safety Considerations for Establishing Minimum Lateral Obstacle Clearance Policies for Utility Facilities in Urban Areas." While the emphasis will be on urban roads, the study will also include rural roads.

One of the research tasks is to conduct a review of other states' lateral obstacle clear zone policies for utilities. To accomplish this task, I would greatly appreciate a copy of your state's *Minimum Design Standards* for all roadway functional classifications (rural and urban). Two examples (Figures 1 and 2) from a Nebraska document, "New and Reconstructed Municipal State Highways" and "Municipal Streets", are enclosed.

Please indicate the references for any Cost-Effectiveness or Benefit-Cost computer models used in establishing any of the minimum design standards in your state. The FHWA (IP-86-14) computer model, entitled "Utility Pole Accident Countermeasures Evaluation (UPACE)" will be used to assist in reviewing policies in Nebraska.

One area of concern in Nebraska is establishing clear zone policies on Municipal Streets where fixed objects such as trees are present. To gain further insight into the issue of fixed objects along municipal streets, I would also greatly appreciate your completing the enclosed "Questionnaire".

I would like to take this opportunity to thank you in advance for your assistance and time in addressing a critical safety problem.

Respectfully,

Edward R. Post, Ph.D., P.E.
Professor

c.c. Mr. Fred Gunderson
NDOR Project Manager

enclosures (3)

LATERAL OBSTACLE CLEAR ZONE POLICIES
FOR FIXED OBJECTS
LOCATED ON MUNICIPAL STREETS

Nebraska Department of Roads
University of Nebraska-Lincoln

June 13, 1989

QUESTIONNAIRE

State Agency ______________________________

Name of Respondent ____________________ Title __________

Address ______________________________

____

____

Phone ____________________

1. Does your state have a lateral clear zone policy for fixed objects such as trees located along a curbed municipal street?

   Yes _____ (Clear zone from back of curb _____ feet)

   No _____

2. Does your state have a lateral clear zone policy for fixed objects such as trees located along a non-curbed municipal street?

   Yes _____ (Clear zone from edge of driving lane _____ feet)

   No _____

3. If you answered yes to either question #1 or #2, does enforcement of your state's lateral clear zone policy for fixed objects such as trees depend on whether a concurrent safety improvement project for streets is planned for a given roadway section?

   Yes _____

   No _____

4. Would a line of utility poles or luminaires located in a clear zone, and partially shielded by trees, be considered for relocation by your state?

Yes _____ [answer parts (a) and (b)]

No _____

(a) Would your state consider using the FHWA "UPACE" computer model to assist in your decision?

Yes _____

No _____

(b) Describe and/or draw a sketch to illustrate the boundary conditions (limits) in which a utility pole would be shielded by a tree(s). (Optional)

001.10 MINIMUM DESIGN STANDARDS – NEW AND RECONSTRUCTED BRIDGES ON MUNICIPAL STATE HIGHWAYS

National Functional Classification	State Functional Classification	Type of Roadway Section	NEW BRIDGES: Roadway Width (Feet)	NEW BRIDGES: Design Loading	NEW BRIDGES: Minimum Vertical Clearance (Feet)	(1) RECONSTRUCTED BRIDGES: Roadway Width (Feet)	RECONSTRUCTED BRIDGES: Inventory Rating Desirable	RECONSTRUCTED BRIDGES: Inventory Rating Minimum	RECONSTRUCTED BRIDGES: Minimum Vertical Clearance (Feet)	BRIDGES TO REMAIN IN PLACE: Roadway Width (Feet)	BRIDGES TO REMAIN IN PLACE: Inventory Rating Desirable	BRIDGES TO REMAIN IN PLACE: Inventory Rating Minimum	BRIDGES TO REMAIN IN PLACE: Minimum Vertical Clearance (Feet)
Interstate	Interstate	N/A	42*	HS20†	16.5	42*	HS20†	HS20†	16.0	30*††	HS20†	HS20†	16.0
Arterial	Expressway or Major Arterial	Curbed	**	HS20	16.5	**	HS20	H15****	14.5	**	HS20	H15****	14.5
		Non-Curbed	***	HS20	16.5	***	HS20	H15****	14.5	28	HS20	H15****	14.5
Collector	Major Arterial	Curbed	**	HS20	14.5	**	HS20	H15****	14.5	**	HS20	H15****	14.5
		Non-Curbed	***	HS20	14.5	***	HS20	H15****	14.5	28	HS20	H15****	14.5

(1) Reconstructed bridges shall mean existing structures to be widened or remodeled.

* Divided roadways, 2-lane each side.

** For New Jersey type bridge curb, the clear roadway width of bridge shall be one foot wider than the gutter line to gutter line width of the approach roadway. For other types of bridge curbs, the clear roadway width of bridge shall be two feet wider than the gutter line to gutter line width of the approach roadway. The gutter line is defined as being one foot inside the back of the approach roadway curb. If the approach roadway on one end of the bridge is curbed and the other end is non-curbed, then the minimum bridge width shall be that which applies to the curbed approach.

*** Bridge roadway width to be same as that required by Board of Public Roads Classifications and Standards "Section 001.01 Minimum Design Standards - New and Reconstructed Bridges on Rural State Highways." If the approach roadway on one end of the bridge is curbed and the other end is non-curbed, then the minimum bridge width shall be the curb-to-curb width.

**** Capacity is adequate if rating analysis does not require load posting. (FHWA exception required for less than HS15).

† HS20 or Alternate Military Loading.

†† FHWA exception required for less than 42 feet.

FIGURE 1

001.15 MINIMUM DESIGN STANDARDS – MUNICIPAL STREETS

Roadway Classification	(1) Design Year ADT	Design Hour DHV	Design Speed (MPH)	(2) Max. Curve (Deg.)	Max. Grade (%)	Number of Lanes	(3) Lane Width (Feet)	Median Width (Feet)	Shoulder Width (Feet)	Width of Shoulder Surfacing (Feet)	Lateral Obstacle Clearance (Feet)	Access Control	Lighting	Bridge Design Loading
Other Arterial	*	*	30	15	8	2	11	0 – As Required	8	N/A	***	None	Full	H-20
Collector	*	*	25	20	10	2	11	None	6	N/A	***	None	Desirable	H-20
Local	*	*	25	30**	10	2	11	None	6	N/A	***	None	Desirable	H-20

Note: The 1965 edition of AASHO "A Policy on Geometric Design of Rural Highways," the 1969 edition of AASHO "Geometric Design Standards for Highways Other than Freeways," the 1973 edition of AASHO "A Policy on Design of Urban Highways and Arterial Streets," and the June 20, 1967 revised AASHO publication "A Policy on Design Standards, Interstate Systems" should be used for other design criteria.

(1) "Design Year" shall be year of initial construction plus 20 years.

(2) 0.06 feet per foot maximum superelevation rate.

(3) Lane widths shall be based on measurements taken from the innermost extremity of curb configuration. Shoulder width shall be measured from back of curb.

* Design shall be based on 250-500 V.P.H. per lane in design year where cross and turning traffic is sufficiently great to require signal control.

** Local street radii can be reduced to 100 feet if compatible with overall development.

*** Minimum lateral obstacle clearance for curbed section shall be 2 feet as measured from back face of curb to front face of obstacle. Minimum lateral obstacle clearance for non-curbed section shall be 8 feet as measured from edge of driving lane and to front face of obstacle. Traffic control devices that conform with the standards of Nebraska Manual of Uniform Traffic Control Devices will be allowed in the lateral obstacle clearance zone, any other object will be considered an obstacle.

These design standards are values for new construction.

Minimum design policy for all classifications shall include seeding or sodding or reestablishment of vegetation of all disturbed areas.

Alley improvements may be made to meet local requirements.

Curb Ramps for the Handicapped shall be included on all New construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23).

FIGURE 2

APPENDIX B

NEBRASKA DEPARTMENT OF ROADS
"MINIMUM DESIGN STANDARDS"

001.01 MINIMUM DESIGN STANDARDS — NEW AND RECONSTRUCTED RURAL STATE HIGHWAYS

(1) Design Number	(2) National Functional Classification	State Functional Classification	(3) Design Year Traffic	Terrain	Design Speed MPH	(4) Horizontal Curve Degree		Maximum Grade Percent	Number of Lanes	Lane Width (Feet)	Median Width (Feet)	Shoulder Width (Feet)	(5) Width of Shoulder Surfacing (Feet)	(6) Hinge Point Distance (Feet)	(7) Lateral Obstacle Clearance (Feet)	(8) Normal ROW Width (Feet)	Access Control
						Desirable	Maximum										
DR1	Interstate	Interstate	N/A	All	70	3	3	3	4 Div.	12	36	6 Lt., 12 Rt.	4 Lt., 10 Rt.	30	35†††	300	Full
DR2	Arterial	Expressway or	Over 750 DHV	Level	70	3	3	3	4 Div.	12	36	5 Lt., 10 Rt.	3 Lt., 8 Rt.	30	30	200	In
"	"	Major Arterial	"	Rolling	60	3.5	4.75	4	4 Div.	12	36	5 Lt., 10 Rt.	3 Lt., 8 Rt.	30	30	200	accordance with NDOR
DR3	Arterial	Expressway or	330 - 750 DHV	Level	70	3	3	3	2**	12	None	10	8	30	30	120	Controlled
"	"	Major Arterial	"	Rolling	60	3.5	4.75	4	2**	12	"	10	8	30	30	120	Access
"	Collector	Expressway or	"	Level	60	3.5	4.75	5*	2**	12	"	10	††	30	30	120	Policy
"	"	Major Arterial	"	Rolling	55	3.5	6	6.5*	2**	12	"	10	††	30	30	120	to the State
DR4	Arterial	Major Arterial	1700 - 3000 ADT	Level	70	3	3	3	2	12	None	8†	††	30	30	120	Highway
"	"	"	"	Rolling	60	3.5	4.75	4	2	12	"	8†	††	30	30	120	System
"	Collector	"	"	Level	60	3.5	4.75	5*	2	12	"	8†	††	30	30	120	"
"	"	"	"	Rolling	55	3.5	6	6.5*	2	12	"	8†	††	30	30	120	"
DR5	Arterial	Major Arterial	850 - 1700 ADT	Level	70	3	3	3	2	12	None	6†	††	20	23	120	"
"	"	"	"	Rolling	60	3.5	4.75	4	2	12	"	6†	††	20	23	120	"
"	Collector	"	"	Level	60	3.5	4.75	5*	2	12	"	6†	††	20	23	120	"
"	"	"	"	Rolling	55	3.5	6	6.5*	2	12	"	6†	††	20	23	120	"
DR6	Arterial	Major Arterial	400 - 850 ADT	Level	70	3	3	3	2	12	None	6†	††	12	22	100	"
"	"	"	"	Rolling	60	4.5	4.75	4	2	12	"	6†	††	12	22	100	"
"	Collector	"	"	Level	55	4.5	6	5.5*	2	12	"	6†	††	12	22	100	"
"	"	"	"	Rolling	55	4.5	6	6.5*	2	12	"	6†	††	12	22	100	"
DR7	Arterial	Major Arterial	Under 400 ADT	Level	70	3	3	3	2	12	None	4†	††	12	20	80	"
"	"	"	"	Rolling	60	4.75	4.75	4	2	12	"	4†	††	12	20	80	"
"	Collector	"	"	Level	55	6	6	5.5*	2	12	"	4†	††	12	20	80	"
"	"	"	"	Rolling	55	6	6	6.5*	2	12	"	4†	††	12	20	80	"

Note The 1984 edition of AASHTO "A Policy on Geometric Design of Highways and Streets" and the June 20, 1967 revised AASHO publication "A Policy on Design Standards, Interstate System" should be used for other design criteria.

(1) All Interstates in the State Functional Classification System are included in Design Number DR1. All Expressways and Major Arterials over 750 future DHV in the State Functional Classification System are included in Design Number DR2. All Expressways and Major Arterials at or below 750 future DHV in the State Functional Classification System are included in Design Numbers DR3 through DR7.

(2) The Director-State Engineer of the Department of Roads shall maintain the National Functional Classification Map in a continually current status.

(3) "Design Year" shall be year of initial construction plus 20 years.

(4) 0.08 feet per foot maximum superelevation rate for entire state.

(5) The Director-State Engineer of the Department of Roads shall maintain the Nebraska Priority Commercial System Map.

(6) Measured from the edge of the driving lane. Roadway sideslopes within this distance will be 6:1 or flatter.

(7) Measured from the edge of the driving lane. Any obstacle within this area must be removed, relocated, or be shielded by a traffic barrier, unless a cost-effective analysis shows that a lesser or no treatment is warranted. Thirty-six inch or smaller flared end sections will not be considered obstacles. Utility facilities existing within these distances shall be relocated in accordance with the NDOR "Policy for Accommodating Utilities on State Highway Rights-of-Way."

(8) Right-of-Way width should not be less than that required for all elements of the cross section and appropriate border areas.

* Maximum grade shown may be one percent steeper for short lengths less than 500 feet.

** 4 lanes allowed by special study.

† 10 feet if on Priority Commercial System.

†† 8 feet if on Priority Commercial System.

††† 30 feet when posted speed is 55 miles per hour.

Minimum design policy for all classifications shall include seeding or reestablishment of vegetation of all disturbed areas.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23.)

FIGURE B-1. MINIMUM DESIGN STANDARDS FOR NEW AND RECONSTRUCTED RURAL STATE HIGHWAYS.

Section 001.03 Standards do not apply to Curbed Urban Highways or Reduced Speed Zone Highways

001.03 MINIMUM DESIGN STANDARDS — RESURFACING, RESTORATION AND REHABILITATION (3R) PROJECTS ON NON-INTERSTATE RURAL STATE HIGHWAYS

Design Year Traffic	(1) Design Speed MPH	(2) Maximum Curve Degree	Maximum Grade Percent	Number of Lanes	Surface Lane Width (Feet)	Minimum Shoulder Width (Feet)	Minimum Width of Shoulder Surfacing (Feet)	(3) Fixed Obstacle Clearance (Feet)	Stopping Sight Distance	Passing Sight Distance	(4) Fill Slopes	(5) Bridges to Remain in Place Roadway Width (Feet)
Over 3000 ADT	55	5	Existing	2	12	9*	8*	30	**	Existing	Existing	44††
1700 - 3000 ADT	55	5	Existing	2	12	6	Existing	20	***	Existing	Existing	40†††
400 - 1700 ADT	55	12.25	Existing	2	12	3	Existing	12	†	Existing	Existing	36†††
Under 400 ADT	55	12.25	Existing	2	11	2	Existing	12	†	Existing	Existing	32†††

(1) Except as noted elsewhere in these standards.

(2) 0.08 feet per foot maximum superelevation rate. Horizontal curves not providing 55 mile per hour design speed shall have advisory curve and speed reduction signs.

(3) The distance shown is the distance from the edge of the driving lane. Any obstacle within this area must be removed, relocated or guard railed, to meet minimum AASHTO guidelines. Utility facilities existing within these distances shall be relocated in accordance with the NDOR "Policy for Accommodating Utilities on State Highway Rights-of-Way." Thirty-six inch flared end sections or less will not be considered as obstacles unless they are encroaching on the existing shoulder width.

(4) Fill slopes will be used in place. Fill slopes under 10 feet in height will not require guard rail protection. Fill slopes 2:1 or flatter, 10 to 20 feet in height and 250 feet or less in length, will not require guard rail protection. Slope and fill combinations exceeding these values may be guard railed if warranted by a cost-effective analysis.

(5) Bridges can remain in place if they are equal to or greater than the approach roadway width (surface lane width plus total shoulder width). If bridge is widened then the Board of Public Roads Classifications and Standards "Section 001.02 Minimum Design Standards — New and Reconstructed Bridges on Rural State Highways" are to be used. Special study may allow bridges to remain in place if within 4 feet of required bridge width.

* If a 4-lane divided facility exists, the minimum inside shoulder width is 3 feet with 2 feet surfaced.

** An average of one vertical curve per mile will be allowed below 55 mile per hour minimum AASHTO stopping sight distance, however, no sag vertical less than 40 mile per hour and crest vertical below 45 mile per hour will be allowed.

*** An average of two vertical curves per mile will be allowed below 55 mile per hour minimum AASHTO stopping sight distance, however, no sag vertical less than 35 mile per hour and crest vertical below 40 mile per hour will be allowed.

† 40 mile per hour for crest vertical curves and existing conditions for sag vertical curves.

†† 39 feet wide for 4-lane divided.

††† 44 feet if on Priority Commercial System.

Minimum design policy shall include seeding or sodding or reestablishment of vegetation of all disturbed areas.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23.)

The above minimum standards do not apply to an interim type surface repair performed on a highway segment programmed for reconstruction. Interim repairs (a minimal thickness of resurfacing only) may be necessary to provide continued serviceability to the traveling public prior to the scheduled reconstruction.

FIGURE B-2. MINIMUM DESIGN STANDARDS FOR RESURFACING, RESTORATION, AND REHABILITATION (3R) PROJECTS ON RURAL STATE HIGHWAYS.

Section 001.04 Standards may be used only for Approved Functionally Classified Scenic - Recreation Roads

001.04 MINIMUM DESIGN STANDARDS — SCENIC - RECREATION - RURAL STATE HIGHWAYS

(1) Design Year Traffic Major Arterial	Design Number	Design Speed MPH	(2) Maximum Curve Degree	Maximum Grade Percent	Number of Lanes	Lane Width (Feet)	Median Width (Feet)	Shoulder Width (Feet)	Width of Shoulder Surfacing (Feet)	(3) Lateral Obstacle Clearance (Feet)		(4) Normal Design ROW Width (Feet)	Access Control
										Desirable	Minimum		
Over 750 DHV	DR3	65	3.5	4**	(Special Study) 2 Minimum	12	36 Ultimate if Required	6 Lt., 10 Rt. 10 on 2 Lane	4 Lt., 8 Rt. 8 on 2 Lane	30	12	200 (4 Lane) 120 (2 Lane)	In accordance with NDOR Controlled Access Policy to the State Highway System
750 - 400 DHV	DR4	65	3.5	4**	2	12	None	10	None	30	12	120	
400 - 200 DHV	DR5	60*	3.5	4**	2	12	None	8	None	20	10	120	*
1700 - 850 ADT	DR6	55*	4.5	4.5**	2	12	None	6	None	12	8	100	*
Under 850 ADT	DR7	50	7.0	7**	2	11***	None	4	None	12	6	80	*

Note 1984 edition of AASHTO "A Policy on Geometric Design of Highways and Streets" should be used for other design criteria.

(1) "Design Year" shall be year of initial construction plus 20 years.

(2) 0.08 feet per foot maximum superelevation rate.

(3) Measured clearances are from the edge of pavement. The desirable dimensions may be reduced to the minimum lateral clearances whenever it is not feasible to meet the specified desirable lateral clearances. Traffic may be protected from obstacles with guard rail when desirable, but guard rail may be deleted if considered more hazardous than the obstacle. Signs, light standards and similar objects may be provided with breakaway bases and may then be placed inside of the minimum lateral clearance.

(4) Right-of-Way width should not be less than that required for all elements of the cross section and appropriate border areas.

* Design speed 65 mile per hour except in rolling terrain.

** The maximum grades may be 1 percent steeper in short sections less than 500 feet in length, or one-way downgrades. For extreme cases, at some underpass and bridge approaches, steeper grades for relatively short lengths may be considered. (For roadways with design numbers DR5 and DR6, highway grades may be 2 percent steeper.)

*** 12 feet lane width desirable.

A minimum 5 feet flat bottom ditch may be used when environmental considerations warrant. Backslopes may be varried to fit conditions.

Minimum design policy for all classifications shall include seeding or reestablishment of vegetation of all distrubed areas.

Minimum design standards within the recreational area shall be consistent with the established speed limits (if it has been reduced from 55 miles per hour) and the topography and use of the facility. Design may be to either urban or rural standards depending upon the terrain conditions.

Speed limits established for these routes shall be those as determined through an engineering analysis of the area by the Department of Roads.

Effort shall be made to preserve the natural environment to the extent possible without compromising the safety of those using the facility, at the speed limits that apply.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23.)

FIGURE B-3. MINIMUM DESIGN STANDARDS FOR SCENIC - RECREATION - RURAL STATE HIGHWAYS.

001.12 MINIMUM DESIGN STANDARDS — NEW AND RECONSTRUCTED MUNICIPAL STATE HIGHWAYS

National Functional Classification	State Functional Classification	Type of Roadway Section	Design Year Traffic	Design Speed MPH	(1) Maximum Grade Percent	(1) Horizontal Curve Degree	(2) Number of Lanes	Lane Width (Feet)	Median Width	Shoulder Width (Feet)	Width of Shoulder Surfacing (Feet)
Interstate	Interstate	N.A.	*	50 - 70	3 - 5	3 - 6.75	4	12	Variable	6 Lt., 12 Rt.	4 Lt., 10 Rt.***
Arterial	Exressway or Major Arterial	Curbed	*	40 - 60**	5 - 7	4.75 - 19	2	11 - 12***	Variable	N/A	N/A
		Non-Curbed	*	40 - 60**	5 - 7	4.75 - 19	2	11 - 12	Variable	4 - 8†	8****
Collector	Major Arterial	Curbed	*	40 - 60**	7 - 11	6.75 - 19	2	11 - 12***	0	N/A	N/A
		Non-Curbed	*	40 - 60**	7 - 11	6.75 - 19	2	11 - 12	0	4 - 8†	8****

Note: The 1984 edition of AASHTO "A Policy on Geometric Design of Highways and Streets" and the June 20, 1967, revised AASHO publication "A Policy on Design Standards, Interstate System" should be used to determine which values within the ranges listed above are suitable for the conditions present on individual projects. These two publications should also be used for other design criteria not listed.

(1) The upper limits of these values should only be used in unusual circumstances. The lower limits of these values should be regarded as desirable.

(2) The actual number of lanes for design shall be based on a capacity analysis using design year traffic and the selected level of service to be obtained.

* Use design hourly volume (DHV) projected to 20 years from year of initial construction.

** FHWA exception required for less than 40 mile per hour. The design speed must be equal to or greater than the posted speed limit.

*** These values do not include width of curb or curb offset.

**** If on Priority Commercial System.

† 10 feet if on Priority Commercial System.

Minimum lateral obstacle clearance for Interstate shall be 30 feet from edge of driving lane. Minimum lateral obstacle clearance for curbed Arterials and Collectors shall be 6 feet from back of curb. Minimum lateral obstacle clearance for non-curbed Arterials and Collectors with posted speeds of 45 miles per hour or lower shall be 15 feet from edge of driving lane. Minimum lateral obstacle clearances for non-curbed Arterials and Collectors with posted speeds of 50 miles per hour or greater shall be those listed in the Board of Public Roads Classifications and Standards "Section 001.01 Minimum Design Standards — New and Reconstructed Rural State Highways." Any obstacle within these clear areas must be removed, relocated, or be shielded by a traffic barrier, unless a cost-effective analysis shows that a lesser or no treatment is warranted. Thirty-six inch or smaller flared end sections will not be considered obstacles. Utility facilities existing within these distances shall be relocated in accordance with the NDOR "Policy for Accommodating Utilities on State Highway Rights-of-Way."

The Director-State Engineer of the Department of Roads shall maintain the National Functional Classification Map in a continually current status.

Minimum design policy for all classifications shall include seeding or reestablishment of vegetation of all disturbed areas.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23.)

FIGURE B-4. MINIMUM DESIGN STANDARDS FOR NEW AND RECONSTRUCTED MUNICIPAL STATE HIGHWAYS.

001.14 MINIMUM DESIGN STANDARDS — RESURFACING, RESTORATION AND REHABILITATION (3R) PROJECTS ON NON-INTERSTATE MUNICIPAL STATE HIGHWAYS

(1) Design Year Traffic	Type of Roadway Section	Design Speed	Maximum Horizontal Curve	Maximum Grade	Number of Lanes	Lane Width (Feet)	Shoulder Width (Feet)	Width of Shoulder Surfacing (Feet)	(2) Fixed Obstacle Clearance (Feet) Posted Speed 45 MPH & Below	(2) Fixed Obstacle Clearance (Feet) Posted Speed 50 MPH & Above	(3) Bridges to Remain in Place Roadway Width (Feet)
Over 3000 ADT	Curbed	Existing Posted Speed	*	Existing	2**	10***	N/A	N/A	2†	2†	20
	Non-Curbed	*	*	*	2**	12	9	8	10††	†††	†††
1700 - 3000 ADT	Curbed	*	*	*	2	10***	N/A	N/A	2†	2†	20
	Non-Curbed	*	*	*	2	12	5	Existing****	10††	†††	†††
Under 1700 ADT	Curbed	*	*	*	2	10	N/A	N/A	2†	2†	20
	Non-Curbed	*	*	*	2	11	2	Existing	10††	†††	†††

(1) "Design Year" shall be year of initial construction plus 20 years.

(2) Any obstacle within this area must be removed, relocated, or be shielded by a traffic barrier, unless a cost-effective analysis shows that a lesser or no treatment is warranted. Thirty-six inch or smaller flared end sections will not be considered obstacles unless they are encroaching on the existing shoulder width. Utility facilities existing within these distances shall be relocated in accordance with the NDOR "Policy for Accommodating Utilities on State Highway Rights-of-Way."

(3) For curbed sections, the clear roadway width of bridge shall not be less than the width of the driving lanes on the approach roadway.

* That which will provide the posted speed. (Existing right angle turns in the central business district or at stop sign or signal controlled intersections are acceptable.)

** Subject to Capacity Analysis.

*** 11 feet is the desirable minimum.

**** A minimum of 4 feet surfaced shoulders is required if the segment is on the Priority Commercial System.

† Measured from back of curb.

†† Measured from the edge of the driving lane.

††† Refer to Board of Public Roads Classifications and Standards "Section 001.03 Minimum Design Standards — Resurfacing, Restoration and Rehabilitation (3R) Projects on Non-Interstate Rural State Highways."

Minimum design policy shall include seeding or sodding or reestablishment of vegetation of all disturbed areas.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23.)

The above minimum standards do not apply to an interim type surface repair performed on a highway segment programmed for reconstruction. Interim repairs (a minimal thickness of resurfacing only) may be necessary to provide continued serviceability to the traveling public prior to the scheduled reconstruction.

FIGURE B-5. MINIMUM DESIGN STANDARDS FOR RESURFACING, RESTORATION, AND REHABILITATION (3R) PROJECTS ON NON-INTERSTATE MUNICIPAL STATE HIGHWAYS.

001.15 MINIMUM DESIGN STANDARDS – MUNICIPAL STREETS

Roadway Classification	(1) Design Year ADT	Design Hour DHV	Design Speed (MPH)	(2) Max. Curve (Deg.)	Max. Grade (%)	Number of Lanes	(3) Lane Width (Feet)	Median Width (Feet)	Shoulder Width (Feet)	Width of Shoulder Surfacing (Feet)	Lateral Obstacle Clearance (Feet)	Access Control	Lighting	Bridge Design Loading
Other Arterial	*	*	30	15	8	2	11	0 – As Required	8	N/A	***	None	Full	H-20
Collector	*	*	25	20	10	2	11	None	6	N/A	***	None	Desirable	H-20
Local	*	*	25	30**	10	2	11	None	6	N/A	***	None	Desirable	H-20

Note: The 1965 edition of AASHO "A Policy on Geometric Design of Rural Highways," the 1969 edition of AASHO "Geometric Design Standards for Highways Other than Freeways," the 1973 edition of AASHO "A Policy on Design of Urban Highways and Arterial Streets," and the June 20, 1967 revised AASHO publication "A Policy on Design Standards, Interstate Systems" should be used for other design criteria.

(1) "Design Year" shall be year of initial construction plus 20 years.

(2) 0.06 feet per foot maximum superelevation rate.

(3) Lane widths shall be based on measurements taken from the innermost extremity of curb configuration. Shoulder width shall be measured from back of curb.

* Design shall be based on 250-500 V.P.H. per lane in design year where cross and turning traffic is sufficiently great to require signal control.

** Local street radii can be reduced to 100 feet if compatible with overall development.

*** Minimum lateral obstacle clearance for curbed section shall be 2 feet as measured from back face of curb to front face of obstacle. Minimum lateral obstacle clearance for non-curbed section shall be 8 feet as measured from edge of driving lane and to front face of obstacle. Traffic control devices that conform with the standards of Nebraska Manual of Uniform Traffic Control Devices will be allowed in the lateral obstacle clearance zone, any other object will be considered an obstacle.

These design standards are values for new construction.

Minimum design policy for all classifications shall include seeding or sodding or reestablishment of vegetation of all disturbed areas.

Alley improvements may be made to meet local requirements.

Curb Ramps for the Handicapped shall be included on all New construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23).

FIGURE B-6. MINIMUM DESIGN STANDARDS FOR MUNICIPAL STREETS.

001.16 MINIMUM DESIGN STANDARDS - RURAL ROADS

(1) Roadway Classification	Design Number	Current ADT	Design Speed (MPH)	(2) Max. Curve (Deg.)	(3) Max. Grade (%)	Number of Lanes	Lane Width (Feet)	(4) Shoulder Width (Feet)	(4) Lateral Obstacle Clearance (Feet)	New and Reconstructed Bridges Roadway Width (100' & Under in Length)	New and Reconstructed Bridges Roadway Width (Over 100' in Length)	Bridges to Remain in Place Roadway Width (100' & Under in Length)	Bridge Design Loading	Surfacing Type Minimum
Other Arterial	ROA1	750-401	50	7.5	7	2	12	6	12	30'	28'	24'	H-20	Agg.
	ROA2	400-251	50	7.5	7	2	11	4	10	30'	28'	22'	H-20	Agg.
	ROA3	250-51	50	7.5	7	2	10	4	10	28'	28'	20'	H-20	Agg.
	ROA4	50-0	40	8.0	8	2	10	3	9	26'	26'	20'	H-15	Agg.
Collector	RC1*	400-251	50	7.5	7	2	11	4	10	30'	28'	22'	H-20	Agg.
	RC2	250-51	50	7.5	7	2	10	4	10	28'	28'	20'	H-15	Agg.
	RC3	50-0	40	10.0	9	2	10	3	Shld. +2	24'	24'	20'	H-15	Agg.
Local	RL1*	400-251	50	7.5	7	2	11	4	Shld. +2	26'	26'	22'	H-20	Agg.
	RL2	250-51	50	7.5	7	2	10	4	Shld. +2	24'	24'	20	H-15	Agg.
	RL3**	50-0	30	23.0	10	2	10	3	Shld. +2	20'	20'	20'	H-15	Agg.

Minimum Maintenance: No standards in effect. All proposed construction or reconstruction shall be submitted to the Board for review in accordance with the rules and regulations for relaxation of standards.

Note: The October 26, 1969, edition of the American Association of State Highway Officials (AASHO) "Geometric Design Guide for Local Roads and Streets - Part 1 - Rural" should be used for other design criteria.

(1) Low water stream crossings may be constructed on very low volume county roads functionally classified as Local or Minimum Maintenance, provided a relaxation of standards has been granted by the Board. New low water stream crossings shall not be constructed on county roads functionally classified as Other Arterial and Collector.

(2) 0.08 feet per foot maximum superelevation rate.

(3) Maximum grades may be exceeded by 2 percent for tangent distance of up to 500 feet in rough terrain.

(4) Minimum lateral obstacle clearance for curbed section shall be 2 feet as measured from back face of curb to front face of obstacle. Minimum lateral obstacle clearance for non-curbed section shall be 8 feet as measured from edge of driving lane and to front face of obstacle. Traffic control devices that conform with the standards of Nebraska Manual of Uniform Traffic Control Devices will be allowed in the lateral obstacle clearance zone, any other object will be considered an obstacle.

* Minimum design criteria for ADT volumes over 400 in the "Collector" and "Local" classifications shall conform to the minimum standards set forth in the "Other Arterial" classification.

** Certain roads falling in the "local" classification, 50-0 A.D.T., require hard surfacing because of the light, granular nature of the soils involved ("Sandhill" soils). In these cases, it shall be permissible to hard surface one 12 feet lane on the minimum section specified for this category.

Minimum design policy for all classifications shall include seeding or reestablishment of vegetation of all disturbed areas.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities (See Section 001.23).

FIGURE B-7. MINIMUM DESIGN STANDARDS FOR RURAL ROADS.

001.17 MINIMUM DESIGN STANDARDS - SCENIC-RECREATION-RURAL ROADS

Roadway Classification	Design Number	Current ADT	Design Speed (MPH)	(1) Max. Curve (Deg.)	(2) Max. Grade (%)	Number of Lanes	Lane Width (Feet)	(3) Shoulder Width (Feet)	(3) Lateral Obstacle Clearance (Feet)	New and Reconstructed Bridges Roadway Width (100' & Under in Length)	New and Reconstructed Bridges Roadway Width (Over 100' in Length)	Bridges to Remain in Place Roadway Width (100' & Under in Length)	Bridge Design Loading	Surfacing Type Minimum
Other Arterial	ROA2	750 - 401	50	7.5	7	2	11	4	10	30'	28'	22'	H-20	Agg.
	ROA3	400 - 251	50	7.5	7	2	10	4	10	28'	28'	20'	H-20	Agg.
	ROA4	250 - 0	40	8.0	8	2	10	3	9	26'	26'	20'	H-15	Agg.
* Collector	RC2	400 - 251	50	7.5	7	2	10	4	10	28'	28'	20'	H-15	Agg.
	RC3	250 - 0	40	10.0	9	2	10	3	Shld. +2	24'	24'	20'	H-15	Agg.
* Local	RL2	400 - 251	50	7.5	7	2	10	4	Shld. +2	24'	24'	20'	H-15	Agg.
	RL3**	250 - 0	30	23.0	10	2	10	3	Shld. +2	20'	20'	20'	H-15	Agg.

Note: The October 26, 1969, edition of the American Association of State Highway Officials (AASHO) "Geometric Design Guide for Local Roads and Streets - Part 1 - Rural" should be used for other design criteria.

(1) 0.08 feet per foot maximum superelevation rate.

(2) Maximum grades may be exceeded by 2 percent for tangent distance of up to 500 feet in rough terrain.

(3) Minimum lateral obstacle clearance for curbed section shall be 2 feet as measured from back face of curb to front face of obstacle. Minimum lateral obstacle clearance for non-curbed section shall be 8 feet as measured from edge of driving lane and to front of obstacle. Traffic control devices that conform with the standards of Nebraska Manual of Uniform Traffic Control Devices will be allowed in the lateral obstacle clearance zone, any other object will be considered an obstacle.

* Minimum design criteria for ADT volumes over 400 in the "Collector" and "Local" classifications shall conform to the minimum standards set forth in the "Other Arterial" classification.

** Certain roads falling in the "local" classification, 50 - 0 A.D.T., require hard surfacing because of the light, granular nature of the soils involved ("Sandhill" soils). In these cases, it shall be permissible to hard surface one 12 feet lane on the minimum section specified for this category.

A minimum 5 feet flat bottom ditch may be used when environmental conditions warrant. Backslopes may be varied to fit conditions.

Minimum design policy for all classifications shall include seeding or reestablishment of vegetation of all disturbed areas.

Minimum design standards within the recreational area shall be consistent with the established speed limits, the topography and use of the facility. Design may be to either urban or rural standards depending on terrain conditions. Minimum design speed permissible 20 mph.

Speed Limits established for these routes shall be those as determined through an engineering analysis of the area by the county or counties having jurisdictional responsibility.

Effort shall be made to preserve the natural environment to the extent possible without compromising the safety of those using the facility at the speed limits that apply.

Curb Ramps for the Handicapped shall be included on all New Construction and Reconstruction of Curbs in Municipalities, Residential Developments and Sanitary and Improvement Districts beyond the Zoning Jurisdiction of the Municipalities. (See Section 001.23).

FIGURE B-8. MINIMUM DESIGN STANDARDS FOR SCENIC - RECREATION - RURAL ROADS.

APPENDIX C

FEDERAL-AID HIGHWAY PROGRAM MANUAL FHPM 6-6-3-2

U. S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

FEDERAL-AID HIGHWAY PROGRAM MANUAL

VOLUME	6	ENGINEERING AND TRAFFIC OPERATIONS
CHAPTER	6	RAILROADS AND UTILITIES
SECTION	3	UTILITIES
SUBSECTION	2	ACCOMMODATION OF UTILITIES

Transmittal 426
November 11, 1988
HNG-12

Par. 1. Purpose
2. Authority
3. Applicability
4. Policy
5. Definitions
6. General Requirements
7. State Highway Agency Accommodation Policies
8. Use and Occupancy Agreements (Permits)
9. Approvals

1. PURPOSE. **To prescribe policies and procedures for accommodating utility facilities and private lines on the right-of-way of Federal-aid or direct Federal highway projects.*

2. AUTHORITY. *23 U.S.C. 109, 111, 116, 123 and 315; 23 CFR 1.23 and 1.27; 49 CFR 1.48(b); Executive Order 11990, 42 FR 26961 (May 24, 1977).*

3. APPLICABILITY. *This directive applies to:*

   a. *new utility installations within the right-of-way of Federal-aid or direct Federal highway projects,*

* Italicized material is published in 23 CFR 645B.

b. *existing utility facilities which are to be retained, relocated, or adjusted within the right-of-way of active projects under development or construction when Federal-aid or direct Federal highway funds are either being or have been used on the involved highway facility. When existing utility installations are to remain in place without adjustments on such projects the highway agency and utility are to enter into an appropriate agreement as discussed in paragraph 8,*

c. *existing utility facilities which are to be adjusted or relocated under the provisions of paragraph 6k, and*

d. *private lines which may be permitted to cross the right-of-way of a Federal-aid or direct Federal highway project pursuant to State law and regulations and the provisions of this directive. Longitudinal use of such right-of-way by private lines is to be handled under the provisions of 23 CFR 1.23(c).*

4. POLICY

a. *Pursuant to the provisions of 23 CFR 1.23, it is in the public interest for utility facilities to be accommodated on the right-of-way of a Federal-aid or direct Federal highway project when such use and occupancy of the highway right-of-way do not adversely affect highway or traffic safety, or otherwise impair the highway or its aesthetic quality, and do not conflict with the provisions of Federal, State or local laws or regulations.*

b. *Since by tradition and practice highway and utility facilities frequently coexist within common right-of-way or along the same transportation corridors, it is essential in such situations that these public service facilities be compatibly designed and operated. In the design of new highway facilities consideration should be given to utility service needs of the area traversed if such service is to be provided from utility facilities on or near the highway. Similarly the potential impact* *on the highway and it users should be considered in the design and location of utility facilities on or along highway right-of-way. Efficient, effective and safe joint highway and utility development of transportation corridors is important along high-speed and high-volume roads, such as major arterials and freeways, particularly those approaching metropolitan areas where space is increasingly limited. Joint highway and utility planning and development efforts are encouraged on Federal-aid highway projects.*

c. *The manner in which utilities cross or otherwise occupy the right-of-way of a direct Federal or Federal-aid highway project can materially affect the highway, its safe operation, aesthetic quality, and maintenance. Therefore, it is necessary that such use and occupancy, where authorized, be regulated by highway agencies in a manner which preserves the operational safety and the functional and aesthetic quality of the highway facility. This directive shall not be construed to alter the basic legal authority of utilities to install their facilities on public highways pursuant to law or franchise and reasonable regulation by highway agencies with respect to location and manner of installation.*

d. *When utilities cross or otherwise occupy the right-of-way of a direct Federal or Federal-aid highway project on Federal lands, and when the right-of-way grant is for highway purposes only, the utility must also obtain and comply with the terms of a right-of-way or other occupancy permit from the Federal agency having jurisdiction over the underlying land.*

5. DEFINITIONS. *For the purpose of this directive, the following definitions shall apply:*

a. *Aesthetic Quality - those desirable characteristics in the appearance of the highway and its environment, such as harmony between or blending of natural and manufactured objects in the environment, continuity of visual form without distracting interruptions, and simplicity of designs which are desirably functional in shape but without clutter.*

b. *<u>Clear Recovery Area</u> - that portion of the roadside, within the highway right-of-way as established by the highway agency, free of nontraversable hazards and fixed objects. The purpose of such areas is to provide drivers of errant vehicles which leave the traveled portion of the roadway a reasonable opportunity to stop safely or otherwise regain control of the vehicle. The clear recovery area may vary with the type of highway, terrain traversed, and road geometric and operating conditions. The American Association of State Highway and Transportation Officials (AASHTO), "Guide for Selecting, Locating, and Designing Traffic Barriers," 1977, should be used as a guide for establishing clear recovery areas for various types of highways and operating conditions.*

c. *<u>Clear Roadside Policy</u> - that policy employed by a highway agency to provide a clear recovery area in order to increase safety, improve traffic operations, and enhance the aesthetic quality of highways by designing, constructing and maintaining highway roadsides as wide, flat, and rounded as practical and as free as practical from natural or manfactured hazards such as trees, drainage structures, nonyielding sign supports, highway lighting supports, and utility poles and other ground-mounted structures. The policy should address the removal of roadside obstacles which are likely to be associated with accident or injury to the highway user, or when such obstacles are essential, the policy should provide for appropriate counter-measures to reduce hazards. Countermeasures include placing utility facilities at locations which protect out-of-control vehicles, using breakaway features, using impact attenuation devices, or shielding. In all cases full consideration shall be given to sound engineering principles and economic factors.*

d. *<u>Direct Federal Highway Projects</u> - those active or completed highway projects such as projects under the Federal Lands Highways Program which are under the direct administration of the Federal Highway Administration (FHWA).*

e. *<u>Federal-Aid Highway Projects</u> - those active or completed highway projects administered by or through a State highway agency which involve or have involved the use of*

Federal-aid highway funds for the development, acquisition of right-of-way, construction or improvement of the highway or related facilities, including highway beautification projects under 23 U.S.C. 319, Landscaping and Scenic Enhancement.

f. *<u>Freeway</u> - a divided arterial highway with full control of access.*

g. *<u>Highway Agency</u> - that department, agency, commission, board, or official of any State or political subdivision thereof, charged by its law with the responsibility for highway administration.*

h. *<u>Highway</u> - any public way for vehicular travel, including the entire area within the right-of-way and related facilities constructed or improved in whole or in part with Federal-aid or direct Federal highway funds.*

i. *<u>Private Lines</u> - privately owned facilities which convey or transmit the commodities outlined in paragraph 5m, but devoted exclusively to private use.*

j. *<u>Right-of-Way</u> - real property, or interests therein, acquired, dedicated or reserved for the construction, operation, and maintenance of a highway in which Federal-aid or direct Federal highway funds are or have been involved in any stage of development. Lands acquired under 23 U.S.C. 319, shall be considered to be highway right-of-way.*

k. *<u>State Highway Agency</u> - the highway agency of one of the 50 States, the District of Columbia, or Puerto Rico.*

l. *<u>Use and Occupancy Agreement</u> - the document (written agreement or permit) by which the highway agency approves the use and occupancy of highway right-of-way by utility facilities or private lines.*

m. *<u>Utility facility</u> - privately, publicly or cooperatively owned line, facility, or system for producing, transmitting, or distributing communications, cable television, power, electricity, light, heat, gas, oil, crude products, water, steam, waste, storm water not connected with highway drainage, or any other similar commodity, including any fire or police signal system or* *street lighting system, which directly or indirectly serves the public. The term utility shall also mean the utility company inclusive of any substantially owned or controlled subsidiary. For the purposes of this section, the term includes those utility-type facilities which are owned or leased by a governmental agency for its own use, or otherwise dedicated solely to governmental use. The term utility includes those facilities used solely by the utility which are a part of its operating plant.*

6. GENERAL REQUIREMENTS

a. Safety. *Highway safety and traffic safety are of paramount, but not of sole, importance when accommodating utility facilities within highway right-of-way. Utilities provide an essential public service to the general public. Traditionally, as a matter of sound economic public policy and law, utilities have used public road right-of-way for transmitting and distributing their services. However, due to the nature and volume of highway traffic, the effect of such joint use on the traveling public must be carefully considered by highway agencies before approval of utility use of the right-of-way of Federal-aid or direct Federal highway projects is given. Adjustments in the operating characteristics of the utility or the highway or other special efforts may be necessary to increase the compatibility of utility-highway joint use. The possibility of this joint use should be a consideration in establishing right-of-way requirements for highway projects. In any event, the design, location, and manner in which utilities use and occupy the right-of-way of Federal-aid or direct Federal highway projects must conform to the clear roadside policies for the highway involved and otherwise provide for a safe traveling environment as required by 23 U.S.C. 109(ℓ)(1).*

b. New Above Ground Installations. *On Federal-aid or direct Federal highway projects, new above ground utility installations, where permitted, shall be located as far from the traveled way as possible, preferably along the right-of-way line. No new* *above ground utility installations are to be allowed within the established clear recovery of the highway unless a determination has been made by the highway agency that placement underground is not technically feasible or is unreasonably costly and there are no feasible alternate locations. In exceptional situations when it is essential to locate such above ground utility facilities within the established clear recovery area of the highway, appropriate countermeasures to reduce hazards shall be used. Countermeasures include placing utility facilities at locations which protect or minimize exposure to out-of-control vehicles, using breakaway features, using impact attenuation devices, using delineation, or shielding.*

c. *<u>Installations Within Freeways</u>*

(1) Each State highway agency shall submit an accommodation plan in accordance with paragraph 7 and paragraph 9 which addresses how the State highway agency will consider applications for longitudinal utility installations within the access control lines of a freeway. This includes utility installations within interchange areas which must be constructed or serviced by direct access from the main lanes or ramps. If a State highway agency elects to permit such use, the plan must address how the State highway agency will oversee such use consistent with this subsection, Title 23, U.S.C., and the safe and efficient use of the highways.

(2) Any accommodation plan shall assure that installations satisfy the following criteria:

(a) The effects utility installations will have on highway and traffic safety will be ascertained, since in no case shall any use be permitted which would adversely affect safety.

(b) The direct and indirect environmental and economic effects of any loss of productive agricultural land or any

productivity of any agricultural land which would result from the disapproval of the use of such right-of-way for accommodation of such utility facility will be evaluated.

(c) These environmental and economic effects together with any interference with or impairment of the use of the highway in such right-of-way which would result from the use of such right-of-way for the accommodation of such utility facility will be considered.

(d) [Reserved]

(e) A utility strip will be established along the outer edge of the right-of-way by locating a utility access control line between the proposed utility installation and the through roadway and ramps. Existing fences should be retained and, except along sections of freeways having frontage roads, planned fences should be located at the freeway right-of-way line. The State or political subdivision is to retain control of the utility strip right-of-way including its use by utility facilities. Service connections to adjacent properties shall not be permitted from within the utility strip.

(3) Nothing in this directive shall be construed as prohibiting a highway agency from adopting a more restrictive policy than that contained herein with regard to longitudinal utility installations along freeway right-of-way and access for constructing and/or for servicing such installations.

d. *Uniform Policies and Procedures. For a highway agency to fulfill its responsibilities to control utility use of Federal-aid highway right-of-way within the State and its political subdivisions, it must exercise or cause to be exercised, adequate regulation over such use and occupancy through the establishment and enforcement of reasonably uniform policies and procedures for utility accommodation.*

e. Private Lines. *Because there are circumstances when private lines may be allowed to cross or otherwise occupy the right-of-way of Federal-aid projects, highway agencies shall establish uniform policies for properly controlling such permitted use. When permitted, private lines must conform to the provisions of this directive and the provisions of 23 CFR 1.23(c) for longitudinal installations.*

f. Direct Federal Highway Projects. *On direct Federal highway projects, the FHWA will apply, or cause to be applied, utility and private line accommodation policies similar to those required on Federal-aid highway projects. When appropriate, agreements will be entered into between the FHWA and the highway agency or other government agencies to ensure adequate control and regulation of use by utilities and private lines of the right-of-way on direct Federal highway projects.*

g. Projects Where State Lacks Authority. *On Federal-aid highway projects where the State highway agency does not have legal authority to regulate highway use by utilities and private lines, the State highway agency must enter into formal agreements with those local officials who have such authority. The agreements must provide for a degree of protection to the highway at least equal to the protection provided by the State highway agency's utility accommodation policy approved under the provisions of paragraph 9b. The project agreement between the State highway agency and the FHWA on all such Federal-aid highway projects shall contain a special provision incorporating the formal agreements with the responsible local officials.*

h. Scenic Areas. *New utility installations, including those needed for highway purposes, such as for highway lighting or to serve a weigh station, rest area or recreation area, are not permitted on highway right-of-way or other lands which are acquired or improved with Federal-aid or direct Federal highway funds and are located within or adjacent to areas of scenic enhancement and natural beauty. Such areas include public park and recreational lands, wildlife and waterfowl refuges, historic sites as described in 23 U.S.C. 138, scenic strips, overlooks, rest areas and landscaped areas. The State highway agency may permit exceptions provided the following conditions are met:*

(1) New underground or aerial installations may be permitted only when they do not require extensive removal or alteration of trees or terrain features visible to the highway user or impair the aesthetic quality of the lands being traversed.

(2) Aerial installations may be permitted only when:

(a) other locations are not available or are usually difficult and costly, or are less desirable from the standpoint of aesthetic quality,

(b) placement underground is not technically feasible or is unreasonably costly, and

(c) the proposed installation will be made at a location, and will employ suitable design and materials, which give the greatest weight to the aesthetic qualities of the area being traversed. Suitable designs include, but are not limited to, self-supporting armless, single-pole construction with vertical configuration of conductors and cable.

(3) For new utility installations within freeways, the provisions of paragraph 6c must also be satisfied.

i. Joint Use Agreements. When the utility has a compensable interest in the land occupied by its facilities and such land is to be jointly occupied and used for highway and utility purposes, the highway agency and utility shall agree in writing as to the obligations and responsibilities of each party. Such joint-use agreements shall incorporate the conditions of occupancy for each party, including the rights vested in the highway agency and the rights and privileges retained by the utility. In any event, the interest to be acquired by or vested in the highway agency in any portion of the right-of-way of a Federal-aid or direct Federal highway project to be vacated, used or occupied by utilities or private lines, shall be adequate for the construction, safe operation, and maintenance of the highway project.

j. *Traffic Control Plan. Whenever a utility installation, adjustment or maintenance activity will affect the movement of traffic or traffic safety, the utility shall implement a traffic control plan and utilize traffic control devices as necessary to ensure the safe and expeditious movement of traffic around the work site and the safety of the utility work force in accordance with procedures established by the highway agency. The traffic control plan and the application of traffic control devices shall conform to the standards set forth in the Manual on Uniform Traffic Control Devices (MUTCD) and Federal-Aid Highway Program Manual (FHPM) 6-4-2-12, Traffic Safety in Highway and Street Work Zones.*

k. *Corrective Measures. When the highway agency determines that existing utility facilities are likely to be associated with injury or accident to the highway user, as indicated by accident history or safety studies, the highway agency shall initiate or cause to be initiated in consultation with the affected utilities, corrective measures to provide for a safer traffic environment. The corrective measures may include changes to utility or highway facilities and should be prioritized to maximize safety benefits in the most cost-effective manner. The scheduling of utility safety improvements should take into consideration planned utility replacement or upgrading schedules, accident potential, and the availability of resources. It is expected that the requirements of this paragraph will result in an orderly and positive process to address the identified utility hazard problems in a timely and reasonable manner with due regard to the effect of the corrective measures on both the utility consumer and the road user. The type of corrective measures are not prescribed. Any requests received involving Federal participation in the cost of adjusting or relocating utility facilities pursuant to this paragraph shall be subject to the provisions of FHPM 6-6-3-1, Utility Relocations, Adjustments and Reimbursement, and FHPM 8-2-3, Highway Safety Improvement Program.*

l. *Wetlands. The installation of privately owned lines or conduits on the right-of-way of Federal-aid or direct Federal highway projects for the purpose of draining adjacent wetlands onto the highway right-of-way is* *considered to be inconsistent with Executive Order 11990, Protection of Wetlands, dated May 24, 1977, and shall be prohibited.*

7. STATE HIGHWAY AGENCY ACCOMMODATION POLICIES. *The FHWA shall use the AASHTO publications, "A Guide for Accommodating Utilities Within Highway Right-of-Way", 1981, and "Guide for Selecting, Locating and Designing Traffic Barriers", 1977, to assist in the evaluation of adequacy of State highway agency utility accommodation policies. As a minimum, such policies shall make adequate provisions with respect to the following:*

   a. *Utilities must be accommodated and maintained in a manner which will not impair the highway or adversely affect highway or traffic safety. Uniform procedures controlling the manner, nature and extent of such utility use shall be established.*

   b. *Consideration shall be given to the effect of utility installations in regard to safety, aesthetic quality, and the costs or difficulty of highway and utility construction and maintenance.*

   c. *The State highway agency's standards for regulating the use and occupancy of highway right-of-way by utilities must include, but are not limited to, the following:*

      (1) *The horizontal and vertical location requirements and clearances for the various types of utilities must be clearly stated. These must be adequate to ensure compliance with the clear roadside policies for the particular highway involved.*

      (2) *The applicable provisions of government or industry codes required by law or regulation must be set forth or appropriately referenced, including highway design standards or other measures which the State highway agency deems necessary to provide adequate protection to the highway, its safe operation, aesthetic quality, and maintenance.*

      (3) *Specifications for and methods of installation; requirements for preservation and restoration of highway facilities, appurtenances, and natural features and vegetation on the right-of-way; and*

limitations on the utility's activities within areas set forth by paragraph 6h should be prescribed as necessary to protect highway interests.

(4) Measures necessary to protect traffic and its safe operation during and after installation of facilities, including control-of-access restrictions, provisions for rerouting or detouring traffic, traffic control measures to be employed, procedures for utility traffic control plans, limitation on vehicle parking and materials storage, protection of open excavations, and the like must be provided.

(5) A State highway agency may deny a utility's request to occupy highway right-of-way based on State law, regulation, or ordinances or the State highway agency's policy. However, in any case where the provisions of this directive are to be cited as the basis for disapproving a utility's request to use and occupy highway right-of-way, measures must be provided to evaluate the direct and indirect environmental and economic effects of any loss of productive agricultural land or any impairment of the productivity of any agricultural land that would result from the disapproval. The environmental and economic effects on productive agricultural land together with the possible interference with or impairment of the use of the highway and the effect on highway safety must be considered in the decision to disapprove any proposal by a utility to use such highway right-of-way.

d. Compliance with applicable State laws and approved State highway agency utility accommodation policies must be assured. The responsible State highway agency's file must contain evidence of the written arrangements which set forth the terms under which utility facilities are to cross or otherwise occupy highway right-of-way. All utility installations made on highway right-of-way shall be subject to written approval by the State highway agency. However, such approval will not be required where so provided in the use and occupancy agreement *agency. However, such approval will not be required where so provided in the use and occupancy agreement for such matters as utility facility maintenance, installation of service connections on highways other than freeways, or emergency operations. [OMB Control Numbers 2125-0522 and 2125-0514]*

e. *The State highway agency shall set forth in its utility accommodation plan detailed procedures, criteria, and standards it will use to evaluate and approve individual applications of utilities on freeways under the provisions of paragraph 6c of this section. The State highway agency also may develop such procedures, criteria and standards by class of utility. In defining utility classes, consideration may be given to distinguishing utility services by type, nature or function and their potential impact on the highway and its user.*

f. *The means and authority for enforcing the control of access restrictions applicable to utility use of controlled access highway facilities should be clearly set forth in the State highway agency plan.*

8. USE AND OCCUPANCY AGREEMENTS (PERMITS). *[OMB Control Number 2125-0522] The written arrangements, generally in the form of use and occupancy agreements setting forth the terms under which the utility is to cross or otherwise occupy the highway right-of-way, must include or incorporate by reference:*

a. *The highway agency standards for accommodating utilities. Since all of the standards will not be applicable to each individual utility installation, the use and occupancy agreement must, as a minimum, describe the requirements for location, construction, protection of traffic, maintenance, access restriction, and any special conditions applicable to each installation.*

b. *A general description of the size, type, nature, and extent of the utility facilities being located within the highway right-of-way.*

c. *Adequate drawings or sketches showing the existing and/or proposed location of the utility facilities within the highway right-of-way with respect to the existing and/or planned highway improvements, the* *d. The extent of liability and responsibilities associated with future adjustment of the utilities to accommodate highway improvements.*

e. The action to be taken in case of noncompliance with the highway agency's requirements.

f. Other provisions as deemed necessary to comply with laws and regulations.

9. <u>APPROVALS</u>

a. Each State highway agency shall submit a statement to the FHWA on the authority of utilities to use and occupy the right-of-way of State highways, the State highway agency's power to regulate such use, and the policies the State highway agency employs or proposes to employ for accommodating utilities within the right-of-way of Federal-aid highways under its jurisdiction. Statements previously submitted and approved by the FHWA need not be resubmitted provided the statement adequately addresses the requirements of this directive. When revisions are deemed necessary, the changes to the previously approved statement may be submitted separately to the FHWA for approval. The State highway agency shall include similar information on use and occupancy of such highways by private lines where permitted. The State shall identify those areas, if any, of the Federal-aid highway systems within its borders where the State highway agency is without legal authority to regulate use by utilities. The statement shall address the nature of formal agreements with local officials required by paragraph 6g. It is expected that the statements required by this directive or necessary revisions to previously submitted and approved statements will be submitted to FHWA within 1 year of the effective date of this directive. [OMB Control Number 2125-0514]

b. Upon determination by the FHWA that a State highway agency's policies satisfy the provisions of 23 U.S.C. 109, 111, and 116, and 23 CFR 1.23 and 1.27, and meet the requirements of this directive, the FHWA will approve their use on Federal-aid highway projects in that State.

c. *Any changes, additions or deletions the State highway agency proposes to the approved policies are subject to FHWA approval.*

d. *When a utility files a notice or makes an individual application or request to a State highway agency to use or occupy the right-of-way of a Federal-aid highway project, the State highway agency is not required to submit the matter to the FHWA for prior concurrence, except under the following circumstances:*

   (1) *The proposed installation is not in accordance with this directive or the State highway agency's utility accommodation policy approved by the FHWA for use on Federal-aid projects.*

   (2) *Longitudinal installations of private lines.*

e. *The State highway agency's practices under the policies or agreements approved under paragraph 9b shall be periodically reviewed by the FHWA.*

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APPENDIX D

COUNTERMEASURE RESEARCH

A number of researchers have focused on possible countermeasures or options for relocating utility and/or light poles. This section provides a composite summary of the recommendations based on their work.

In 1980, Jones studied a major pole relocation project implemented along a four-lane major arterial in Knoxville, Tennessee in 1974 (35). Before the pole relocation, the roadway had a relatively high incidence of personal injuries and fatalities. Jones found that the number of personal injuries and fatalities was essentially eliminated along the 3.25 kilometer section as a result of (1) increasing the lateral offset of utility poles from the back of the curb to approximately 6 feet, or to the back of the sidewalk; (2) locating poles on one side of the street; and (3) increasing pole spacing to 150 feet. From 1963 to 1979, the ADT varied from approximately 20,000 to 32,000.

Fox, Good, and Joubert performed a benefit-cost analysis to evaluate a series of countermeasures and concluded that new luminaire installations should be made either breakaway or wrap-around (6). Using the statistical concept of "relative risk," they argued that poles at the curb line are over 3 times more likely to be involved in an accident than those more than 3 meters away. If poles are required, they should be offset at least 3 meters from the road edge and should not be located on the outside of curves or near curve entry and exit points. They also emphasized the importance of pavement skid resistance.

A study performed by the American Public Works Association (APWA) found that the joint use of utility poles by two or more types of utilities is widely incorporated to reduce costs and minimize street clutter (36). The utilities which commonly are involved with joint use of utility poles are power, telephone, telegraph, and cable TV. Although joint trenching or undergrounding was not as widespread, one of the more common combinations was electric and telephone lines in the same trench, in various combinations with telegraph, cable TV, and other signal cables where no interference conditions exist.

Zegeer and Cynecki listed a number of possible roadway treatments or countermeasures for reducing the frequency or severity of utility poles accidents (18). The potential countermeasures include the following:

Locating Utility Lines Underground: This countermeasure involves removing the utility poles and burying the utility lines underground.

Increasing the Lateral Offset of Poles: This countermeasure is aimed at reducing utility pole accidents by increasing the distance of the poles from the roadway edge.

Reducing the Number of Poles: This countermeasure can be achieved by a number of treatments such as multiple use of poles by different utilities, placing poles on only one side of the street, and increasing pole spacings.

Utilizing Breakaway Poles: This countermeasure is directed at reducing utility pole accident severity, not accident frequency.

Protective Devices: This countermeasure involves the use of guardrail or impact attenuators near utility poles to protect the motorist and reduce the severity of the accident.

Other Countermeasures: The use of occupant restraints (seat belts and shoulder harnesses) would reduce the utility pole accident severity. Combinations of countermeasures could also be implemented such as increasing the lateral offset of poles and reducing the number of poles.

APPENDIX E

SEAT BELT EFFECTIVENESS

Safety belts have been found to reduce the number of serious injuries by 50% and the number of fatalities by 60 to 70% (37). When an automobile is impacted in the rear, front, or side, the percent of reduction in injury is 50%, 55%, or 60%, respectively. In the ability to reduce death or injury, the lap belt is 30% effective, while the lap and shoulder belt combination is 60% effective.

APPENDIX F

MANUAL METHOD COST-EFFECTIVENESS PROCEDURE FORMS

COST-EFFECTIVENESS ANALYSIS PROCEDURE FOR UTILITY POLE ACCIDENTS

FORM A: SITE DESCRIPTION

Road Name or Route Identification: ____________________

Beginning Milepoint: ________ Ending: ________ Length: ________ (Miles)

Area Type (Urban or Rural) ____________ Curb (Yes or No) ________

Right-of-Way Width: ____________ Shoulder Width: ____________ Feet

Current Daily Traffic Volume (ADT_C): ________ Speed Limit: ________ mph.

Expected Future Change in ADT = ___ percent/yr. or ___ percent in ___ yrs.

Utility Pole Location (one side or two): ____________

	No. of Poles	Pole Spacing	Poles/Mile	Avg. Pole Offset
Side 1:	________	________ ft.	________	________ ft.
Side 2:	________	________ ft.	________	________ ft.
Total:	________		________	________ ft.

Type of Utility Poles and Lines:

Side 1	Side 2 (if applicable)	
____	____	Wood telephone poles
____	____	Wood power poles carrying <69 KV lines
____	____	Non-wood poles
____	____	Heavy wood distribution and transmission poles
____	____	Steel transmission poles

Utility Pole Accident Data: ☐ Available ☐ Not Available

Utility Pole Accidents = ________ (total) for _____ years.

Utility Pole Accidents/Mile/Year (A_C) = $\frac{\text{No. of Utility Pole Accidents}}{\text{(Sec. Length) x (Yrs. of Data)}}$

A_C = ______ Utility Pole Accidents per mile per year

Percent injury & fatal Utility Pole Accidents = ______ %

Total Injuries: ____________ Total Fatalities: ____________

Coverage of other heavy fixed objects within 30 feet of roadway. Refer to Figures 10 to 15 to determine coverage factor (C_F) to use (check one):

____ 10% Roadside Coverage (See Figure 10)
____ 20% Roadside Coverage (See Figure 11)
____ 30% Roadside Coverage (See Figure 12)
____ 40% Roadside Coverage (See Figure 13)
____ 60% Roadside Coverage (See Figure 14)
____ 80% Roadside Coverage (See Figure 15)

COST-EFFECTIVENESS ANALYSIS PROCEDURE FOR UTILITY POLE ACCIDENTS

FORM B: COUNTERMEASURE DESCRIPTION

(Complete Form B for Each Countermeasure)

Countermeasure Number ____ of ____

Countermeasure to be Evaluated (Check One):

_____ Placement of Utility Lines Underground (Check One)

- _____ Telephone lines
- _____ Electric distribution lines <69 KV, direct bury, one phase
- _____ Electric distribution lines <69 KV, direct bury, three phase
- _____ Electric distribution lines <69 KV, conduit
- _____ Electric transmission lines >69 KV
- _____ Other: ______________________________

_____ Pole Relocation from ____ feet to ____ feet from the edge of the pavement

_____ Increase Pole Spacing from ____ to ____ feet. Thus the total number of poles on the section will be __________ which translates to __________ poles per mile of roadway section.

_____ Pole Relocation from _____ feet to _____ feet from the edge of the roadway and Increase Pole Spacing to _____ feet which translates to ______ poles per mile of roadway section.

_____ Add Breakaway Pole Feature to _____ percent of poles. Expected reduction in injury and fatal accidents = ______ %

_____ Multiple Pole Use (for a section with utility poles on both sides of the roadway) by removing utility lines from the line of poles closest to the roadway. The average offset of the remaining line of utility pole is ____ feet from the edge of the roadway. The number of poles on the section would be ____ translating to ____ poles per mile of section.

Expected change in annual maintenance cost (total section):

- _____ No change
- _____ Increase of $______ per year
- _____ Decrease of $______ per year
- _____ Unknown (assume $0 change if unknown)

Expected initial project costs (Specify):

- $__________ Per Mile: ______________________________
- $__________ Per Pole: ______________________________
- $__________ Total: ______________________________

Expected countermeasure service life = _____ years (assume 20 years if unknown)

Interest rate = ______ percent per year (assume 12 percent if unknown)

COST-EFFECTIVENESS ANALYSIS PROCEDURE FOR UTILITY POLE ACCIDENTS

FORM C: WORK FORM

(Complete Form C for Each Countermeasure: See Coding Instructions)

STEP 1 - Complete the Site Inventory Form (Form A).

STEP 2 - Complete the Countermeasure Description Form (Form B). One Countermeasure Description Form should be completed for each countermeasure.

Countermeasure No.:___________

Countermeasure Description: ______________________________

STEP 3 - Compute Average Traffic Volume over the Project Life (ADT_A)

Current ADT = ______ = ADT_C

- Method 3-A - Annual Growth Rate (g)

Annual Traffic Growth Rate (g) = ___ percent

Adjustment Factor = ______ = F_A (From Table 11)

$ADT_A = (ADT_C) \times F_A$ = _______x_______ = ________

- Method 3-B - Overall Growth Rate (G)

Overall Growth Rate (G) = ___ percent

$ADT_A = ADT_C \frac{(2 + G/100)}{2}$ = _____ $\frac{(2 + \_\_\_/100)}{2}$ = _____

STEP 4 - Determine Utility Pole Accidents Without Treatment (A_B)

- Method 4-A - Accident Predictive Model - Nomograph

ADT_A = _________ (Step 3)

Existing Pole Density = ___________ poles/mile (Form A)

Existing Pole Offset = ___________ feet (Form A)

A_B = ____________ Accidents per mile per year (Nomograph, Figure 8)

Note: If Method 4-A is used, $A_2 = A_B$.

COST-EFFECTIVENESS ANALYSIS PROCEDURE FOR UTILITY POLE ACCIDENTS

FORM C: WORK FORM

(Complete Form C for Each Countermeasure: See Coding Instructions)

- Method 4-B - Existing Accident Data

A_C = ______ accidents per mile per year based on existing accident experience (Form A)

Adjustment Factor to Convert Utility Pole Accident Experience From A_C to A_B

A_1 (From Nomograph, Figure 8) = ____________

ADT$_C$ = ____________ (Form A)
Existing Pole Density = ________ poles/mile (Form A)
Existing Pole Offset = ________ feet (Form A)

A_2 (From Nomograph, Figure 8) = ____________

ADT$_A$ = ____________ (Step 3)
Existing Pole Density = ____________ poles/mile (Form A)
Existing Pole Offset = ____________ feet (Form A)

$A_B = (A_C) \times (A_2/A_1)$ = ___ x (___/___) = ___ Accidents per mile per year

STEP 5 - Determine the Accident Reduction Factor (R_A) for utility pole accidents

A_F (from Nomograph, Figure 8) = ____________ Accidents per mile per year

ADT$_A$ = ____________ (Step 3)
Proposed Pole Density = ____________ poles/mile (Form B)
Proposed Pole Offset = ____________ feet (Form B)

A_2 = ____________ Accidents per mile per year (Step 4)

$R_A = \frac{A_2 - A_F}{A_2}$ = ______ - ______ = __________

R_A = __________ % Reduction in Utility Pole Accident Frequency

For the Breakaway Pole Countermeasure, Skip Steps 6 and 7, go to Step 8.

STEP 6 - Select the Roadside Adjustment Factor (H_R)

Skip for the Breakaway Pole Countermeasure

Coverage Factor (C_F) = ______________ (Form A)

H_R = ________ (0 to 1.0) from Tables 3, 4, 5 or 6.

COST-EFFECTIVENESS ANALYSIS PROCEDURE FOR UTILITY POLE ACCIDENTS

FORM C: WORK FORM

(Complete Form C for Each Countermeasure: See Coding Instructions)

STEP 7 - Compute the Number of Accidents Reduced (ΔA)

$\Delta A = (A_B) \times (R_A) \times (H_R) \times (L)$

ΔA = _____ x _____ x _____ x _____ = _______ Accidents per year

STEP 8 - Select the Average Cost Per Utility Pole Accident (C_A)

C_A = $7,007 based on 1981 NSC costs or $______ based on ____

____ agency costs.

For the breakaway pole countermeasure, skip Step 9 and go to Step 10B

STEP 9 - Compute Accident Benefits Due to Reduced Accident Occurrences (B_A)

$B_A = (\Delta A) \times (C_A)$

B_A = ______ x $______ = $______ per year.

STEP 10 - Compute Accident Benefits Due to a Reduction in Accident Severity (B_S)

- Step 10-A - For all countermeasures except breakaway devices. Only for sections having speeds less than 45 mph.

  $B_S = (A_B) \times (1 - H_R) \times (R_A) \times (\Delta C_A) \times (L)$ [For ΔC_A, See Table 12]

  B_S = ______ x (1 - ______) x ______ x $______ x ______ = $______ per year

- Step 10-B - For the breakaway pole countermeasure only .

  $B_S = (A_B) \times (\Delta C_A) \times (L)$ [For ΔC_A, See Table 13]

  B_S = _______ x $_______ x _______ = $_______ per year

STEP 11 - Compute Total Accident Benefits (B_T)

$B_T = B_A + B_S$

B_T = $______ + $______ = $______ per year

COST-EFFECTIVENESS ANALYSIS PROCEDURE FOR UTILITY POLE ACCIDENTS

FORM C: WORK FORM

(Complete Form C for Each Countermeasure: See Coding Instructions)

STEP 12 - Determine the Change in Maintenance Costs (C_M)

C_M = \$______ per year. Use \$0 if unknown

STEP 13 - Determine Countermeasure Installation Costs (C_I)

- Method 13-A - Cost Per Mile (C_L)

  $C_I = (C_L) \times (CRF^i_n) \times (L)$

  C_I = \$______ x ______ x ______ = \$______ per year

- Method 13-B - Cost Per Utility Pole (C_P)

  $C_I = (C_P) \times (P_L) \times (CRF^i_n) \times (L)$

  C_I = \$______ x ______ x ______ x ______ = \$______ per year

- Method 13-C - Total Project Cost (C_S)

  $C_I = (C_S) \times (CRF^i_n)$ \$______ x ______

  C_I = \$________ per year

STEP 14 - Calculate Total Project Cost (C_T)

$C_T = C_M + C_I$

C_T = \$______ + \$______ = \$______ per year.

STEP 15 - Calculate the Benefit-To-Cost Ratio (B/C)

$B/C = \frac{B_T}{C_T}$ = ______

COST-EFFECTIVENESS ANALYSIS PROCEDURE FOR UTILITY POLE ACCIDENTS

FORM D: COMPARISON OF COUNTERMEASURE

(Use This Form Only if 2 or More Countermeasures Are Being Considered at the Same Location)

STEP 16 - Conduct Incremental Benefit-to-Cost Ratio Analysis ($\Delta B/\Delta C$).

List the Countermeasures in Order by Cost (C_T) from Lowest to Highest for those with a B/C ratio greater than 1.0 (or other acceptable minimum value).

Rank	Counter-measure Number	Total Annual Cost (C_T)	Total Annaul Benefits (B_T)	B/C Ratio	Compare	Incremental Change In Costs (ΔC)	Incremental Change In Benefits (ΔB)	Incremental Benefit/Cost Ratio $\Delta B/\Delta C$
Lowest Cost (C_T)								
2nd Lowest Cost								
3rd Lowest Cost								
4th Lowest Cost								
Highest Cost								

STEP 17 - Evaluate Available Funding and Other Agency Constraints

Select the remaining countermeasure with the highest incremental benefits to highest incremental costs.

Countermeasure No. and Description: ____________________

Countermeasure Cost: $__________ per year

Is funding available to complete project (Yes or No) __________

Do any other agency constraints prohibit implementation (Yes or No)__________

If yes, Describe: ____________________

If the project is unacceptable, select the countermeasure with the next highest incremental benefits to incremental costs until project is selected.

Countermeasure No. and Description: ____________________

Countermeasure Cost: $__________ per year

STEP 18 - Record Project Details

Selected Project: ____________________

Project Cost: $__________ per year

Total Project Cost: $__________ Change in Annual Maintenance Costs: $__________

Annual Accident Benefits: $__________

Utility Pole Accidents Reduced per year: __________

B/C Ratio = __________

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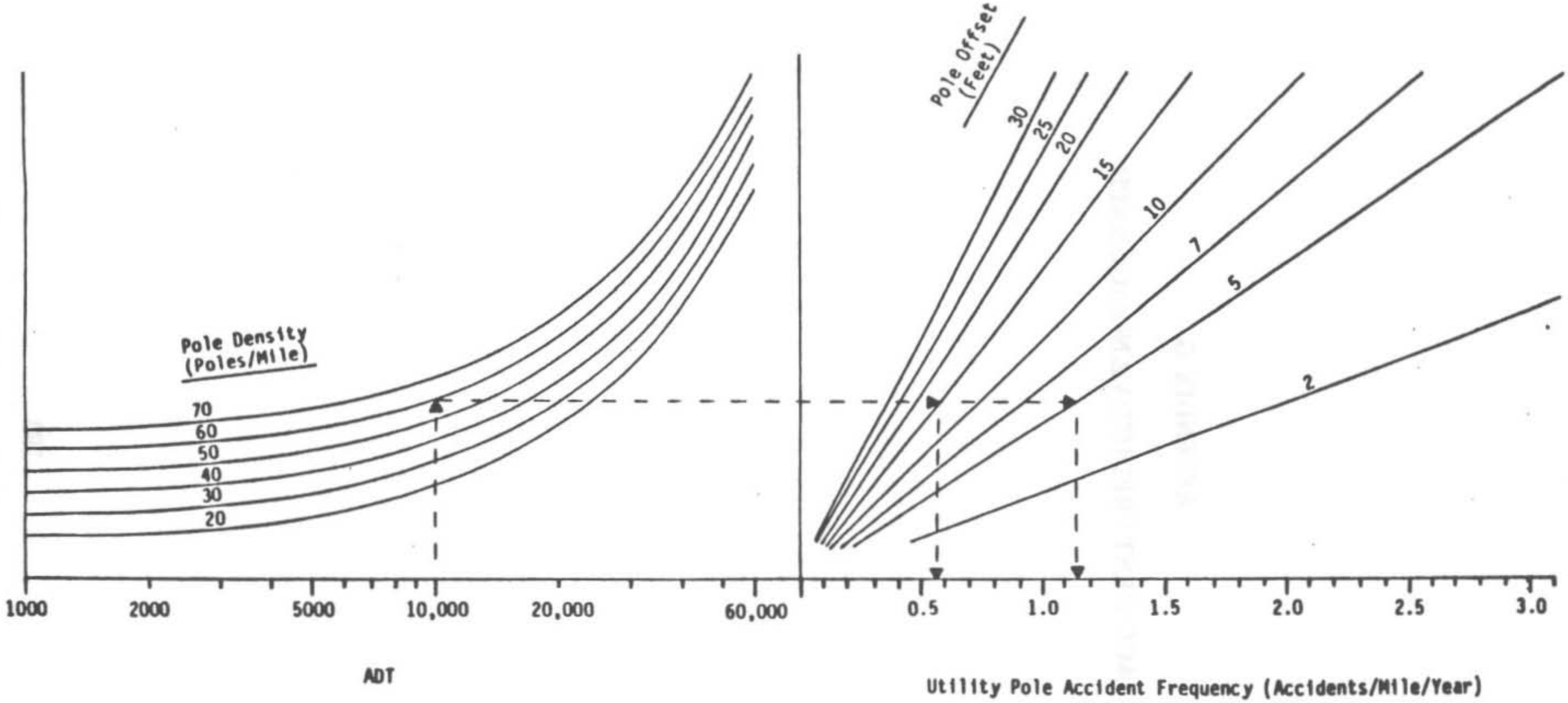
APPENDIX G

ACCIDENT PREDICTIVE NOMOGRAPH



Note:

1 foot = 0.3 meter
1 pole/mile = 0.6 poles/km
1 accident/mile/year = 0.6 accidents/km/year

FIGURE G-1. NOMOGRAPH FOR PREDICTING ACCIDENT FREQUENCY.

APPENDIX H.

FORMULATION OF ROADSIDE ADJUSTMENT FACTOR USING 16 EQUATIONS

As discussed in the text, the effectiveness of the utility pole countermeasure is greatly affected by the general characteristics of the roadside. Since most roadside situations involve other fixed objects, curbs, or sideslopes, the net reduction in roadside accidents will be less than the reduction in utility pole accidents.

For any given roadside configuration, Glennon's hazard model can be used to estimate roadside adjustment factors (23). The adjustment factors can theoretically transform predicted accident reductions for utility pole countermeasures into net roadside accident reductions. The roadside adjustment factor formulation which is included in the following section was taken from the FHWA report by Zegeer and Cynecki (18).

Background

Glennon's hazard index model can be simplified for a noncontiguous roadside obstacle (with a constant side slope and with no fixed objects) to:

$$H = E_f \times S \times P[Y \geq s] \times L$$

where

H = hazard index, number of fatal and nonfatal injury accidents per year,

E_f = frequency of encroachments, number of encroachments per mile per year,

S = severity index, number of fatal and nonfatal injury accidents per total accidents

$P[Y \geq s]$ = probability that the lateral encroachment (Y) of a vehicle equals or exceeds the lateral distance (s) of the obstacle from the roadway edge, accidents per encroachment, and

L = one mile section length.

Graham and Hardwood indicate that this formulation over-predicts the roadside hazard by factors ranging from 2 to 8 depending on the magnitude of slopes and the coverage of fixed objects (33). In studying the NCHRP 247 results, Zegeer and Parker found some apparent flaws in the NCHRP 148 formulation. For example, not every vehicle that encounters a 6:1 fill-slope will have an accident (reported or otherwise), yet the formulation assumes that every encounter guarantees an accident. Thus, a more appropriate formulation of the simplified model would be as follows:

$$H = E_f \; x \; S \; x \; R_1 \; x \; P[Y \geq s]$$

where

R_1 = reporting level of roadside encounters with the obstacle, reported accidents per accident.

In order to estimate adjustment factors that will transform the predicted utility pole accident reductions into net roadside accident reductions, it is more appropriate to look at conditional probability that any accident (including PDO's) will occur, given that a roadside encroachment has occurred. This conditional probability, P_1, is given in its general form as:

$$P_1 = R_1 \; x \; P[Y \geq s]$$

Encroachment frequency is not included in the conditional probability equation.

The application of the upgraded model to specific roadside configurations and utility pole accident countermeasures is much more complex than the general application described above. Thus, the model has 16 basic forms depending on the order in which each of the five roadside features are encountered. These features include utility poles, other fixed objects, curbs, sideslopes, and what is called the nonclear zone. The nonclear zone is that area from about 20 to 30 feet from the roadway where there is some increased level of hazard presented by steeper sideslopes, nonclear trees and foliage, rocks, fences, walls, etc.

The basic form of the model requires one other consideration to account for the additive contributions of various roadside features. The coverage factors for both utility poles and other fixed objects must be known. The 16 different roadside cases are as follows:

	Roadside Feature Order (from edge of road outward)			
Roadside Cases	1st	2nd	3rd	4th
1	U.P.	F.O.	Slope	NCZ
2	U.P.	Slope	F.O.	NCZ
3	U.P.	Slope	NCZ	---
4	F.O.	U.P.	Slope	NCZ
5	F.O.	Slope	U.P.	NCZ
6	F.O.	Slope	NCZ	U.P.
7	Slope	U.P.	F.O.	NCZ
8	Slope	F.O.	U.P.	NCZ
9	Slope	U.P.	NCZ	---
10	Slope	F.O.	NCZ	---
11	Slope	NCZ	U.P.	---
12	Curb	U.P.	F.O.	NCZ
13	Curb	F.O.	U.P.	NCZ
14	Curb	U.P.	NCZ	---
15	Curb	F.O.	NCZ	---
16	Curb	NCZ	U.P.	---

where

U.P. = Utility Pole

F.O. = Fixed Object

Slope = Side Slope

NCZ = Nonclear Zone

The equations for each of the 16 different cases are given below, where *C* is the coverage factor, *R* is the reporting level, *L* is the lateral placement in feet, *U* is the subscript for utility pole, *F* is the subscript for fixed object, *S* is the subscript for side slope, *N* is the subscript for nonclear zone, and K is the subscript for curb. The reporting level is the estimated percent of fixed object accidents which are reported, since not all collisions are reportable.

CASE 1

$$P_I = (C_U)(R_U)P[Y \geq L_U] + (C_F)(1-C_U)(R_F)P[Y \geq L_F] + (1-C_F)(1-C_U)(R_S)P[L_S \leq Y \leq L_N] + (1-C_F)(1-C_U)(R_N)P[Y > L_N]$$

CASE 2

$$P_I = (C_U)(R_U)P[Y \geq L_U] + (1-C_U)(R_S)P[L_S \leq Y \leq L_F] + (1-C_U)(C_F)(R_F)P[Y \geq L_F] + (1-C_U)(1-C_F)(R_S)P[L_F \leq Y \leq L_N] + (1-C_U)(1-C_F)(R_N)P[Y \geq L_N)$$

CASE 3

$$P_I = (C_U)(R_U)P[Y \geq L_U] + (1-C_U)(R_S)P[L_S \leq Y \leq L_N] + (1-C_U)(R_N)P[Y > L_N]$$

CASE 4

$$P_I = (C_F)(R_F)P[Y \geq L_F] + (1-C_F)(C_U)(R_F)P[Y \geq L_U] + (1-C_F)(1-C_U)(R_S)P[L_S \leq Y \leq L_N] + (1-C_F)(1-C_U)(R_N)P[Y > L_N]$$

CASE 5

$$P_I = (C_F)(R_F)P[Y \geq L_F] + (1-C_F)(R_S)P[L_S \leq Y \leq L_U] + (1-C_F)(C_U)(R_U)P[Y \geq L_U] + (1-C_F)(1-C_U)(R_S)P[L_U \leq Y \leq L_N] + (1-C_F)(1-C_U)(R_N)P[Y > L_N)$$

CASE 6

$$P_I = (C_F)(R_F)\,P[Y \geq L_F] + (1-C_F)(R_S)\,P[L_S \leq Y \leq L_N] + (1-C_F)(R_N)\,P[Y > L_N]$$

CASE 7

$$\begin{aligned} P_I = {} & (R_S)\,P[L_S \leq Y \leq L_U] + (C_U)(R_U)\,P[Y \geq L_U] \\ & + (1-C_U)(R_S)\,P[L_U \leq Y \leq L_F] \\ & + (1-C_U)(C_F)(R_F)\,P[Y > L_F] \\ & + (1-C_U)(1-C_F)(R_S)\,P[L_F \leq Y \leq L_N] \\ & + (1-C_U)(1-C_F)(R_N)\,P[Y \geq L_N] \end{aligned}$$

CASE 8

$$\begin{aligned} P_I = {} & (R_S)\,P[L_S \leq Y \leq L_F] + (C_F)(R_F)\,P[Y \geq L_F] \\ & + (1-C_F)(R_S)\,P[L_F \leq Y \leq L_U] \\ & + (1-C_F)(C_U)(R_U)\,P[Y \geq L_U] \\ & + (1-C_F)(1-C_U)(R_S)\,P[L_U \leq Y \leq L_N] \\ & + (1-C_F)(1-C_U)(R_N)\,P[Y > L_N] \end{aligned}$$

CASE 9

$$\begin{aligned} P_I = {} & (R_S)\,P[L \leq Y \leq L_U] + (C_U)(R_U)\,P[Y \geq L_U] \\ & + (1-C_U)(R_S)\,P[L_U \leq Y \leq L_N] \\ & + (1-C_U)(R_N)\,P[Y > L_N] \end{aligned}$$

CASE 10

$$\begin{aligned} P_I = {} & (R_S)\,P[L_S \leq Y \leq L_F] + (C_F)(R_F)\,P[Y \geq L_F] \\ & + (1-C_F)(R_S)\,P[L_F \leq Y \leq L_N] \\ & + (1-C_F)(R_N)\,P[Y > L_N] \end{aligned}$$

CASE 11

$$P_I = (R_S)\, P[L_S \leq Y \leq L_N] + (R_N) P[Y > L_N]$$

CASE 12

$$\begin{aligned} P_I = {} & (R_K)\, P[Y \leq L_U] + (C_U)(R_U) P[Y \geq L_U] \\ & + (1-C_U)(R_K)\, P[L_U \leq Y \leq L_F] \\ & + (1-C_U)(C_F)(R_F)\, P[Y \geq L_F] \\ & + (1-C_U)(1-C_F)(R_K)\, P[L_F \leq Y \leq L_N] \\ & + (1-C_U)(1-C_F)(R_N)\, P[Y > L_N] \end{aligned}$$

CASE 13

$$\begin{aligned} P_I = {} & (R_K)\, P[Y \leq L_F] + (C_F)(R_F) P[Y \geq L_F] \\ & + (1-C_F)(R_K)\, P[L_F \leq Y \leq L_U] \\ & + (1-C_F)(C_U)(R_U)\, P[Y \geq L_U] \\ & + (1-C_F)(1-C_U)(R_K)\, P[L_U \leq Y \leq L_N] \\ & + (1-C_F)(1-C_U)(R_N)\, P[Y > L_N] \end{aligned}$$

CASE 14

$$\begin{aligned} P_I = {} & (R_K)\, P[Y \leq L_U] + (C_U)(R_U) P[Y \geq L_U] \\ & + (1-C_U)(R_K)\, P[L_U \leq Y \leq L_N] \\ & + (1-C_U)(R_N)\, P[Y > L_N] \end{aligned}$$

CASE 15

$$\begin{aligned} P_I = {} & (R_K)\, P[Y < L_F] + (C_F)(R_F) P[Y \geq L_F] \\ & + (1-C_F)(R_K)\, P[L_F < Y < L_N] \\ & + (1-C_F)(R_N)\, P[Y > L_N] \end{aligned}$$

CASE 16

$$P_I = (R_K)\, P[Y \leq L_N] + (R_N)\, P[Y > L_N]$$

In calculating the value for conditional probability (P_I), an important variable is the utility pole coverage factor (C_U). It is calculated using Glennon's model which calculates the roadway shadow length for each object.

Assuming that a single fixed-object such as a pole has a 0.5-ft square dimension, the equation for shadow length is then given as follows:

$$Shadow\ length = 0.5 + 6\csc\theta + 0.5\cot$$

where

θ = average encroachment angle

11 deg. - rural

7 deg. - urban

Thus, the shadow length in urban and rural areas is 53.81 ft/pole and 34.52 ft/pole, respectively. The utility pole coverage factor (C_U) is given by the following expression:

$$C_U = \frac{SL \times PD}{\frac{5280\ ft}{mile}}$$

where

C_U = utility pole coverage factor,

SL = shadow length in feet per pole, and

PD = pole density in poles per mile.

The 16 basic equations have many different variables which must be input into the expressions. To determine some of these variables, several assumptions, simplifications, classifications, and parameter values were applied.

Zegeer and Cynecki have listed many example values for these variables which are shown in Table H-1 (18). The values for the probability of an encroachment equaling or exceeding a lateral distance for urban and rural areas are presented in Figures H-1 and H-2, which were taken from the study by Glennon and Wilton (24). Zegeer and Cynecki also obtained the reporting level factors from NCHRP 247 through the process of subjective estimation.

Calculation Of Roadside Adjustment Factor

A step-by-step procedure was presented by Zegeer and Cynecki for the calculation of the "Roadside Adjustment Factor (H_R)". It is summarized in the following section.

Step #1:

For the existing roadside condition, list the values of the following variables:

L_U = average lateral offset of the utility poles

L_F = average lateral offset of fixed objects

L_S = distance of break in slope for rural areas

L_N = lateral distance at which the nonclear zone begins

Step #2:

Repeat step #1 for the condition expected after the countermeasure is implemented.

Step #3:

For both the before and after situations, the appropriate equation must be chosen from the 16 available cases. This is based on the order of the obstacles from the roadway edge.

TABLE H-1

Example Values Used in the Roadside Hazard Adjustment Model

Coverage Factor Classes for Utility Poles (C_U) and Fixed Objects (C_F)

C_U 0.065, 0.130, 0.195, 0.260
C_F 0.10, 0.35, 0.65, 0.90

Lateral Placement of Roadside Hinge Point L_X (in Feet)

$L_X = 10$

Lateral Placements of Utility Poles (L_U) and Fixed Objects (L_F) in Feet

Rural $L_U = 5, 10, 15, 20$
$L_F = 5, 10, 15, 20$

Urban $L_U = 2, 5, 10, 15$
$L_F = 2, 5, 10, 15$

Lateral Placement of Non-Clear Zone (L_N) in Feet

Rural $L_N = 30$
Urban $L_N = 20$

Exceedance Probabilities for Lateral Displacement of Encroaching Vehicles

Rural		Urban	
Lateral Displacement (Feet)	Probability	Lateral Displacement (Feet)	Probability
5	0.96	2	0.92
10	0.87	5	0.77
15	0.70	10	0.57
20	0.58	15	0.40
30	0.30	20	0.27

Reporting Level Factors

Fixed Objects $R_F = 0.90$
Utility Poles $R_U = 0.90$
Curbs $R_K = 0.10$
Nonclear Zone $R_N = 0.50$
Slopes

Fill Slope	Cut Slope	R_S
10:1	6:1	0.05
6:1	4:1	0.20
4:1	3:1	0.30
3:1	2:1	0.60

Note: 1 foot = 0.3 m

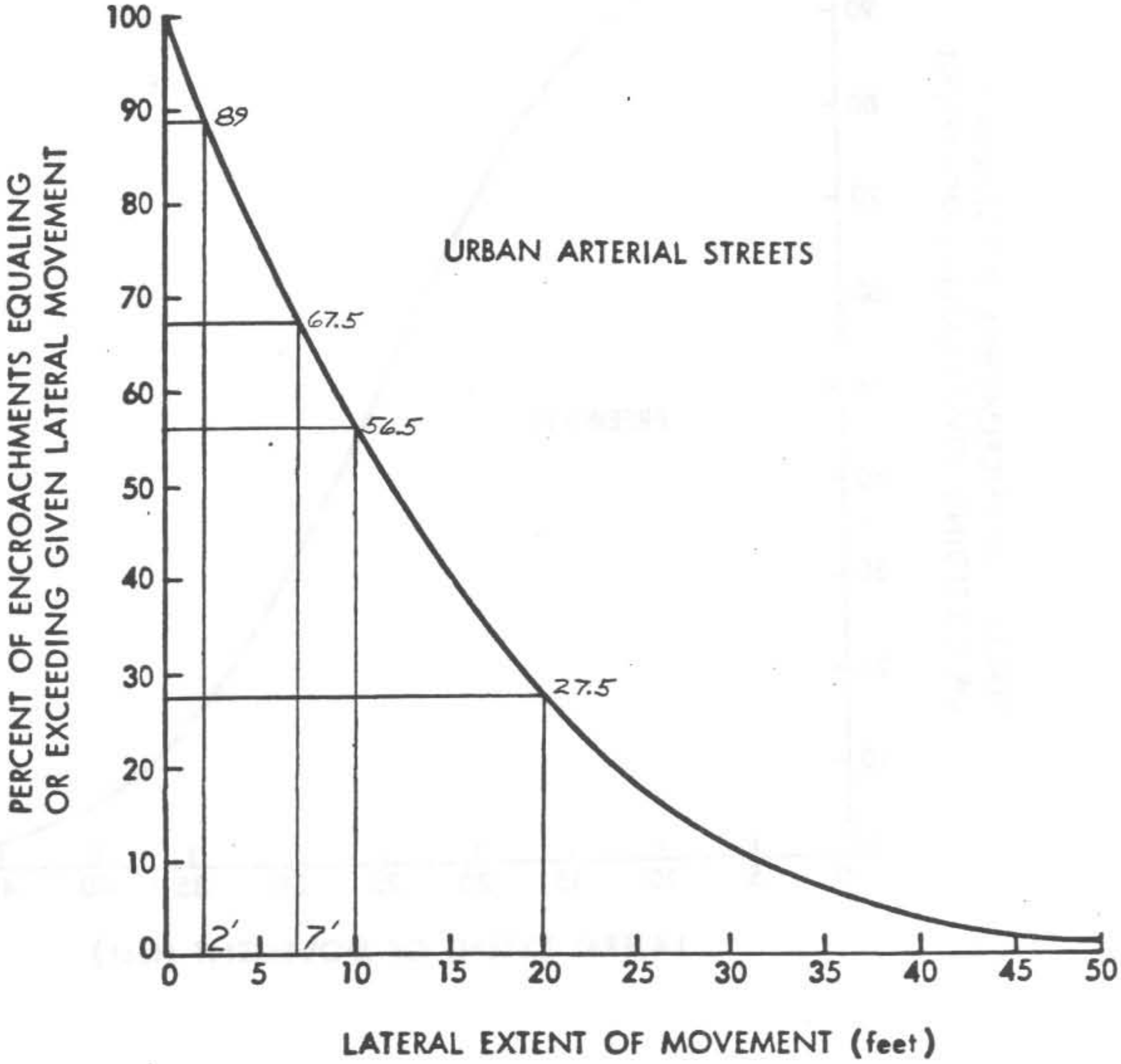


FIGURE H-1. PROBABILITY OF AN ENCROACHMENT EQUALING OR EXCEEDING A LATERAL DISTANCE FOR URBAN AREAS.

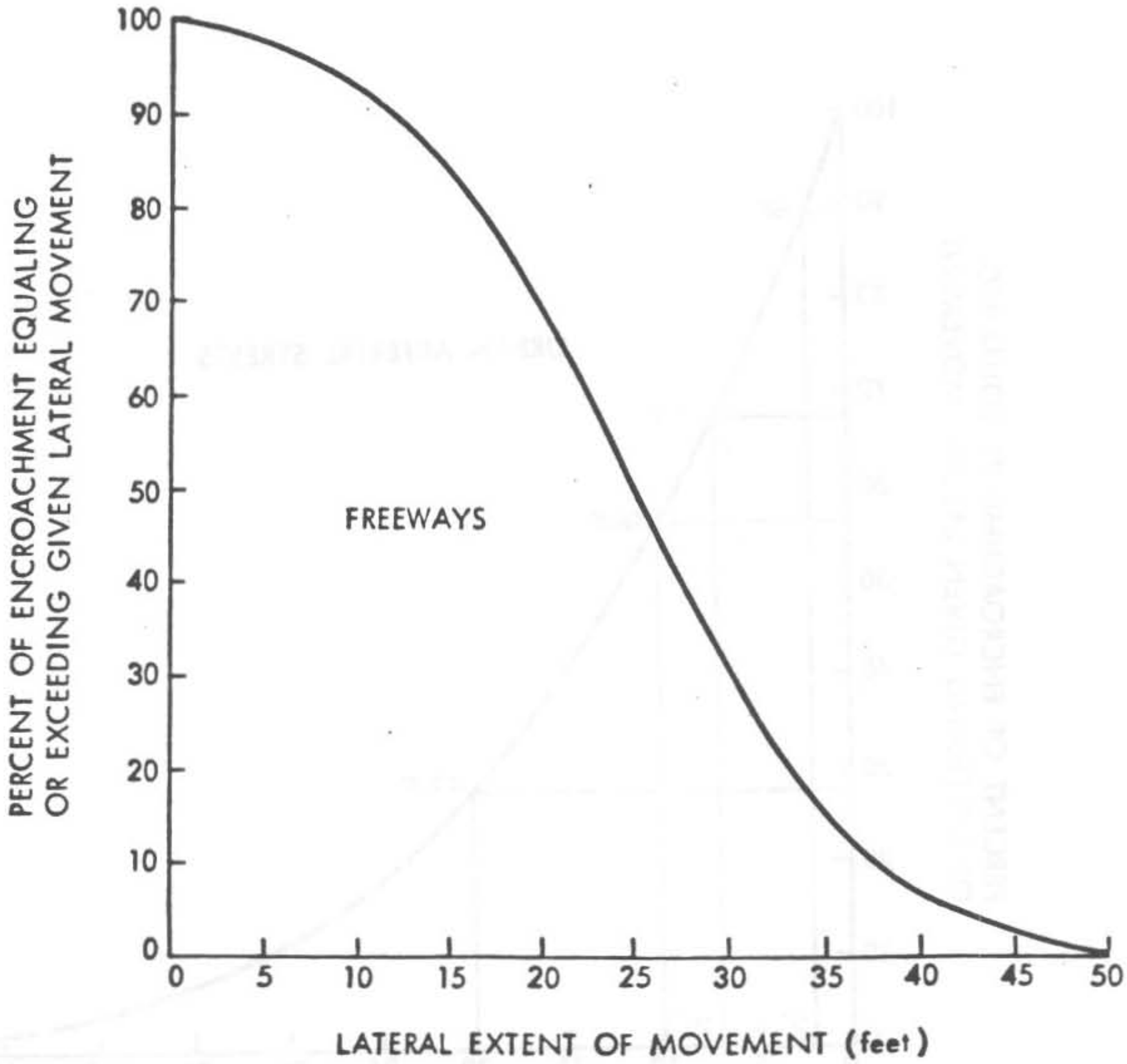


FIGURE H-2. PROBABILITY OF AN ENCROACHMENT EQUALING OR EXCEEDING A LATERAL DISTANCE FOR RURAL AREAS.

Step #4:

Determine the values for the following variables in the before and after situations:

R_U = reporting level for utility pole accidents,

R_F = reporting level for fixed-object accidents,

R_S = reporting level for slope accidents,

R_N = reporting level for nonclear zone accidents,

R_K = reporting level for curb accidents, and

$P[Y \geq L_N]$ = probability of equaling or exceeding the nonclear zone lateral distance.

Step #5:

The probability of a utility pole accident (P_U) must now be computed for both the before and after cases, as shown in the following expression. It is done independently of other roadside conditions.

$$P_U = (C_U) \ x \ (R_U) \ x \ P[Y \geq L_U]$$

Step #6:

The expected change in the probability of a utility pole accident (ΔP_U) is calculated by the following expression:

$$\Delta P_U = P_{U1} - P_{U2}$$

where

P_U = change in the utility pole accident probability after a countermeasure has been implemented,

P_{U1} = probability of a utility pole accident in the before condition, and

P_{U2} = probability of a utility pole accident after the countermeasure has been implemented.

Step #7:

The probability of any roadside accident (P_I) occurring for both the before and after conditions must now be calculated. This is performed by using one of the 16 equations for both the before and after situations.

Step #8:

The expected change in the probability of any roadside accident (ΔP_I) is calculated by the following expression:

$$\Delta P_I = P_{I1} - P_{I2}$$

where

ΔP_I = change in any roadside accident probability after countermeasure has been implemented,

ΔP_{I1} = probability of a roadside accident in the before condition, and

ΔP_{I2} = probability of a roadside accident in the after condition.

Step #9:

The roadside adjustment factor (H_R) can now be calculated by the following equation:

$$H_R = \Delta P_I / P_U$$

Step #10:

With the hazard reduction factor known, the net reduction in total roadside object accidents due to a utility pole countermeasure can be calculated by multiplying H_R by the expected reduction in utility pole accidents.

Example Calculation

The calculation of the "Roadside Adjustment Factor (H_R)" can be shown through the use of the following field example, as shown in Figure H-3.

Given: (Urban Location)

Before:

Pole Density = 40 poles/mile
Pole Average Lateral Offset = 2 ft from curb
Fixed Object Coverage = 3 trees/200 ft
Fixed Object Average Lateral Offset = 7 ft from curb
Nonclear Zone = 20 ft from curb

After:

Pole Density = 40 poles/mile
Pole Average Lateral Offset = 10 ft from curb
Fixed Object Coverage = 3 trees/200 ft
Fixed Object Average Lateral Offset = 7 ft from curb
Nonclear Zone = 20 ft from curb

C_U = (SL x PD) / (5280 ft/mile)
C_U = (53.81 ft/pole x 40 poles/mile) / (5280 ft/mile)
C_U = 0.408

C_F = 0.50 (18)

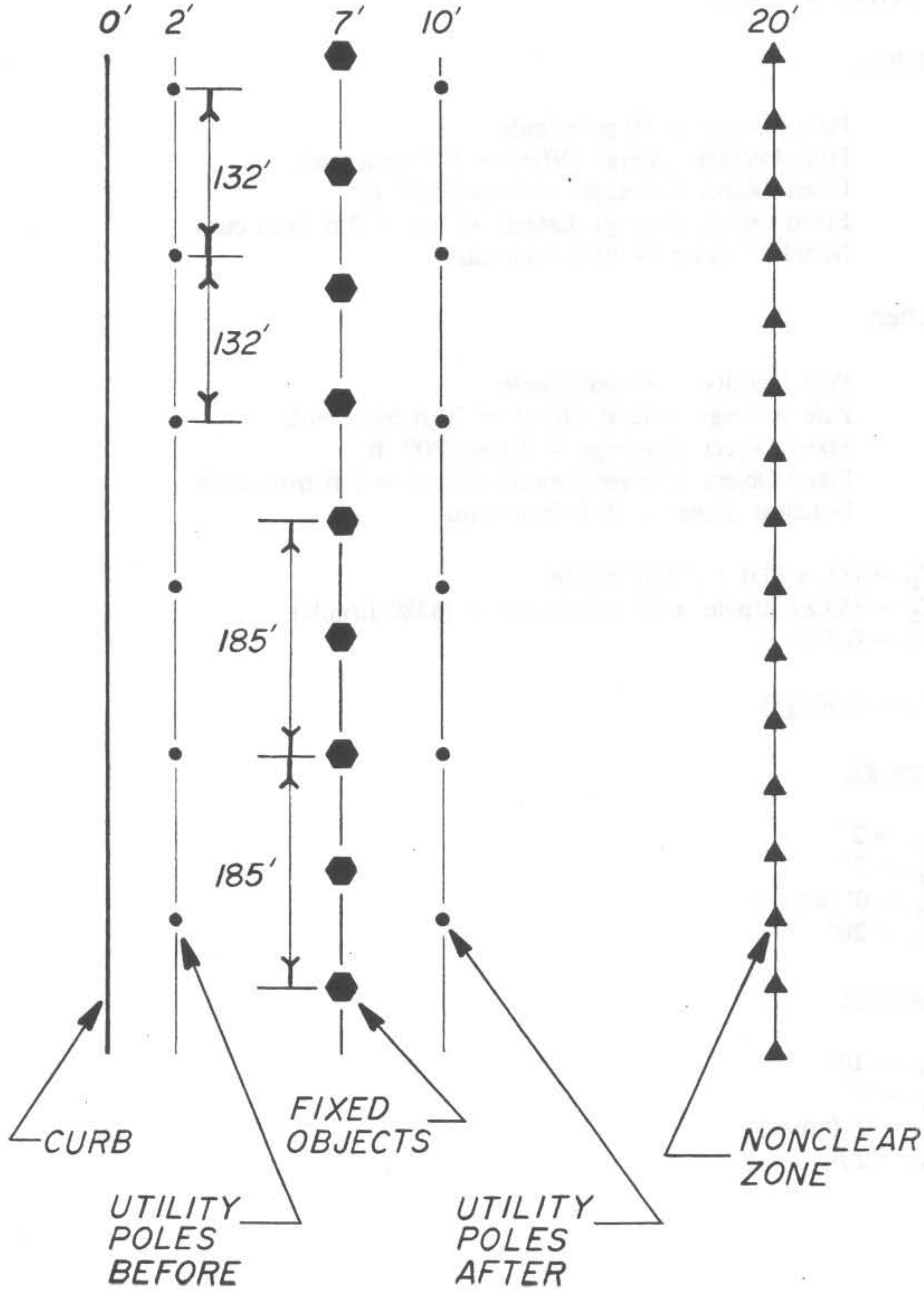
Step #1:

L_U = 2'
L_F = 7'
L_S = 0' (urban)
L_N = 20'

Step #2:

L_U = 10'
L_F = 7'
L_S = 0' (urban)
L_N = 20'

FIGURE H-3. SKETCH OF EXAMPLE PROBLEM



Step #3:

Before: Use Case 12

After: Use Case 13

Step #4:

Before:

$R_U = 0.90$
$R_F = 0.90$
$R_S = 0$ (urban)
$R_N = 0.50$
$R_K = 0.10$
$P[Y>L_N] = 0.275$

After:

$R_U = 0.90$
$R_F = 0.90$
$R_S = 0$ (urban)
$R_N = 0.50$
$R_K = 0.10$
$P[Y>L_N] = 0.275$

Step #5:

$$P_U = (C_U) \times (R_U) \times P[Y \geq L_U]$$

Before: $P_{U1} = (0.408)(0.90)(0.89) = 0.327$
After: $P_{U2} = (0.408)(0.90)(0.565) = 0.207$

Step #6:

$$P_U = P_{U1} - P_{U2} = 0.327 - 0.207 = 0.120$$

Step #7:

Before: (Case 12)

$$P_I = (0.10)(0.11) + (0.408)(0.90)(0.89) + (0.592)(0.10)(0.215) + (0.592)(0.50)(0.90)(0.675) + (0.592)(0.50)(0.10)(0.40) + (0.592)(0.50)(0.50)(0.275)$$

$$= 0.011 + 0.3268$$
$$+ 0.0127$$
$$+ 0.1798$$
$$+ 0.0118$$
$$+ 0.0407$$
$$= 0.5828$$

After: (Case 13)

$$P_I = (0.10)(0.325) + (0.50)(0.90)(0.675)$$
$$+ (0.50)(0.10)(0.11)$$
$$+ (0.50)(0.408)(0.90)(0.565)$$
$$+ (0.50)(0.592)(0.10)(0.29)$$
$$+ (0.50)(0.592)(0.50)(0.275)$$

$$= 0.0325 + 0.3038$$
$$+ 0.0055$$
$$+ 0.1038$$
$$+ 0.0086$$
$$+ 0.0407$$
$$= 0.4949$$

Step #8:

$$\Delta P_I = P_{I1} - P_{I2} = 0.0879$$

Step #9:

$$\Delta H_R = \Delta P_I / \Delta P_U = 0.0879/0.120 = \underline{0.7325}$$

Compare: 0.75 (Tables developed by Zegeer and Cynecki) (18)
0.749 (UPACE Computer Program) (20)

APPENDIX I

LITERATURE REVIEW ON BREAKAWAY UTILITY POLES

BREAKAWAY CONCEPTS

The breakaway concept for utility poles is considered a realistic alternative for improving the hazards of a dangerous roadside object at a reasonable cost. The breakaway concept must be designed so that the wooden utility poles can be easily and economically modified in the field.

Most of the research and development for breakaway mechanisms pertaining to utility poles has taken place in the 1970's and 1980's although the concept for luminaires and sign structures was developed in the 1960's. The major breakaway designs are described in the following section. The discussion focuses on (1) the Breakaway Concept; (2) the Breakaway Stub Concept; (3) the Slipbase Concept; and (4) the Hawkins Breakaway Concept (HBS).

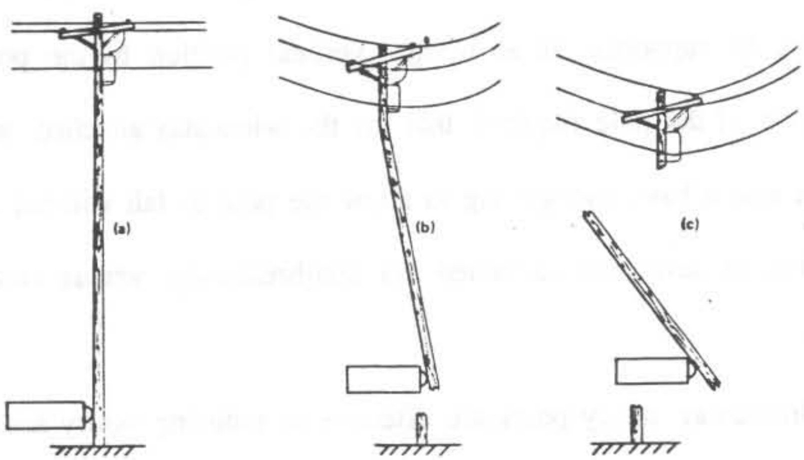
Breakaway Concept

Early development of the breakaway concept for wooden utility poles was conducted at Southwest Research Institute (SwRI) in 1973 (38). Later, this concept became what was called the "RETROFIX" concept. The objective was to determine the feasibility of modifying wooden utility poles so that they would break away when struck by out-of-control vehicles causing only minor injuries to the occupants. The modified breakaway utility pole still had to maintain its structural integrity in order to sustain service loads under environmental conditions.

The method used to effect the weakened zone in the poles was to drill and cut a pattern of holes and grooves at two different heights, as shown in Figure I-1. The idea of exposing parts of the inner pole to the elements was a concern. But, it was determined that a field application of preservatives would offer protection. Another concern was that under high winds or icing, failure may occur at one or both weakened sections; although, design calculations showed that the modified pole would withstand the environmental loading conditions.

FIGURE I-1.

SCHEMATIC OF BREAKAWAY CONCEPT



It was concluded that the probability of a severe injury or fatality was almost certain for an unmodified utility pole accident for unrestrained occupants even at speeds as low as 15 mph. The possible hazard due to a detached pole from the breakaway concept was determined to be problematical.

Breakaway Stub Concept

The breakaway stub concept was developed at the University of Nebraska in 1979 (7). The design consisted of retrofitting existing poles to yield when struck by an errant vehicle at low speeds.

The stub concept worked in a similar manner to the design developed by SwRI. The stub portion between the lower and upper breakaway joints, as shown in Figure I-2, would release when struck by an errant vehicle, thereby allowing the vehicle to decelerate at a rate which was tolerable to its occupants. The breakaway joints were made by drilling a horizontal row of 1-in. diameter holes, as shown in Detail A of Figure I-2.

After the vehicle knocked out the breakaway stub, the upper portion of the pole would fall and be supported in an upright vertical position by the power lines. The final upright position of the pole required that (a) the wires stay attached to the insulators, and (b) the wires would have enough sag to allow the pole to fall without snapping the wires.

The impact severities computed for non-breakaway versus breakaway utility poles showed that:

1. Breakaway utility poles are effective in reducing injury accidents.
2. Standard size vehicle impacts are less severe than subcompact vehicle impacts.
3. A standard size vehicle colliding with a non-breakaway utility pole was equal in severity to a subcompact size vehicle colliding with a breakaway utility pole.

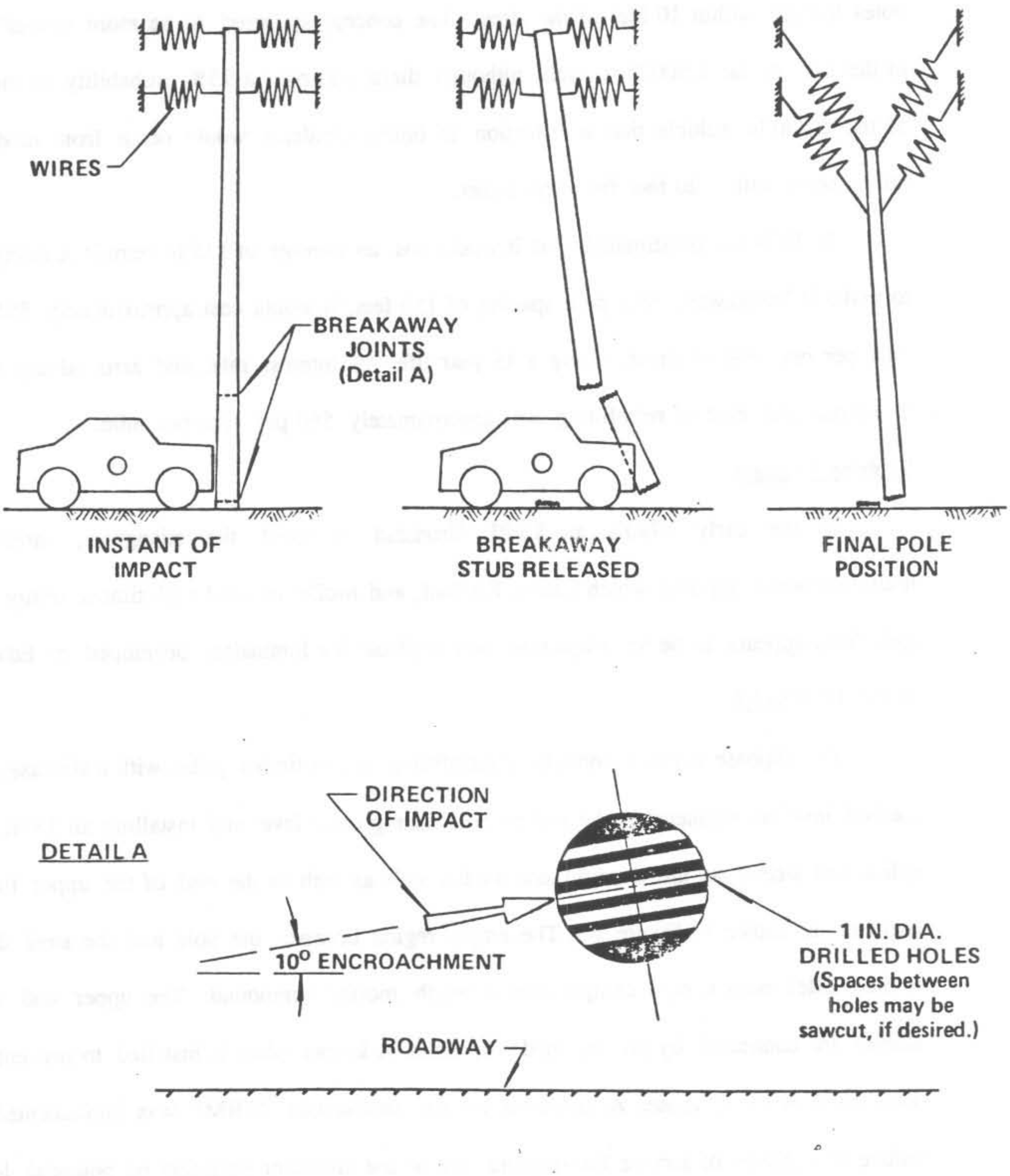


FIGURE I-2. SKEMATIC OF BREAKAWAY STUB CONCEPT.

The breakaway concept was shown to be very cost effective, particularly for utility poles located within 10 feet of the street. The concept appeared to be more cost-effective in the case of the 4,500 lb. vehicle, although there was over a 95% probability in the case of the 2,250 lb. vehicle that a reduction in injury accidents would occur from modifying utility poles within 20 feet from the street.

In 1979 it was estimated that it would cost an average of $15 to retrofit a utility pole to make it breakaway. At a pole spacing of 150 feet, it would cost approximately $540 per mile per one side of street. Using a 15 year life, 7% interest rate, and zero salvage value, the annualized cost of retrofitting was approximately $60 per year per mile.

Slipbase Concept

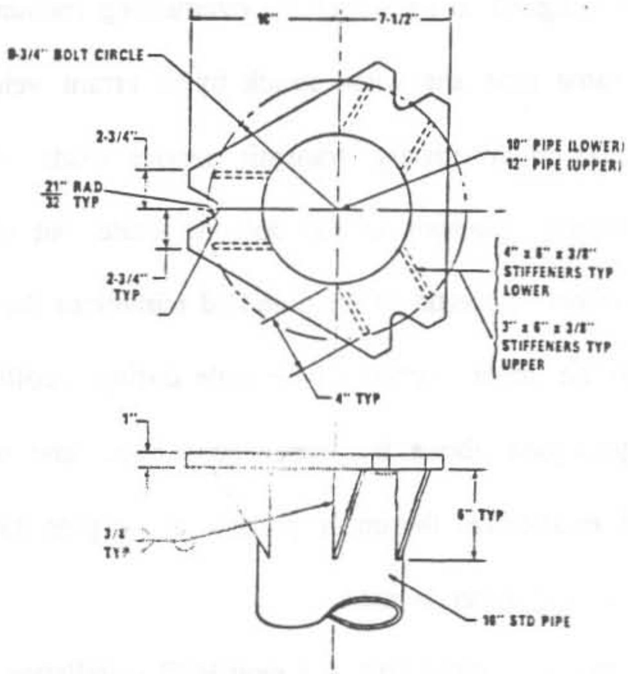
In the early 1980's, at SwRI, Bronstad designed the triangular, three-bolt, multidirectional slipbase which Labra, Kimball, and McDevitt used with timber utility poles (39). This appears to be an adaptation of a slipbase for luminaires developed by Edwards in the 1960's (40).

The slipbase concept consists of retrofitting in situ timber poles with a slipbase. This method involves segmenting the timber pole near ground level and installing an 18-in. long cylindrical sleeve on the exposed end of the stub as well as the end of the upper timber segment, as shown in Figure I-3. The empty region between the pole and the steel sleeve is then filled with a high compressive strength mortar compound. The upper and lower sleeves are connected by pretensioned slip bolts. A keeper plate is installed to prevent the bolts from working loose. A crossarm release mechanism (CRM) was implemented to reduce the chance of service line rupture due to the crossarm snagging on potential lower crossarms.

The breakaway slipbase for wooden utility poles has been shown to considerably reduce the severity of impact for an errant vehicle and its occupants (8). The utility industry should also be pleased with the fact that modifying existing poles with a slipbase design should not significantly affect the pole's ability to perform properly under severe wind or ice loads.

FIGURE I-3.

DETAIL OF SLIPBASE CONCEPT



The costs associated with implementing the slipbase have not been estimated (39). The cost for materials for the steel slipbase unit was estimated at $200.

Hawkins Breakaway System (HBS)

The Hawkins Breakaway System (HBS) was developed at TTI in 1985 in an effort to build on the conventional slipbase technology (41). This system was named after D.L. Hawkins who was the first to suggest slip bases on roadside structures and was influential in their early development (42).

The HBS consists of a lower connection or slipbase, an upper connection or hinge mechanism, and structural support cables, as shown in Figures I-4 and I-5 (41). The slipbase and hinge mechanism activate upon impact and are intended to reduce the inertial effects of the pole on the errant vehicle while minimizing the impact on utility service.

The slipbase was designed to withstand the overturning moments imposed by service wind loads and at the same time slip when struck by an errant vehicle. The upper hinge mechanism is sized so as to adequately transmit service loads while hinging during a collision to allow the bottom segment of the pole to rotate out of the way. The upper connection reduces the effective inertia of the pole and minimizes the effect of any variation in hardware attached to the upper portion of the pole during a collision.

The overhead guys (one above the upper connection and one below the neutral conductor) are intended to stabilize the upper portion of the pole during a collision and to insure proper behavior of the upper portion.

It was estimated that the initial cost of a new HBS installation for a single pole unit would be \$1675 (including \$800 for the slipbase, upper mechanism, overhead guys, and miscellaneous hardware; \$570 for equipment and labor; and \$125 for a new pole). After a collision in which the HBS was fully activated, repair costs are estimated at \$1000 (including labor, equipment, a new pole, and replacement of some of the breakaway hardware).

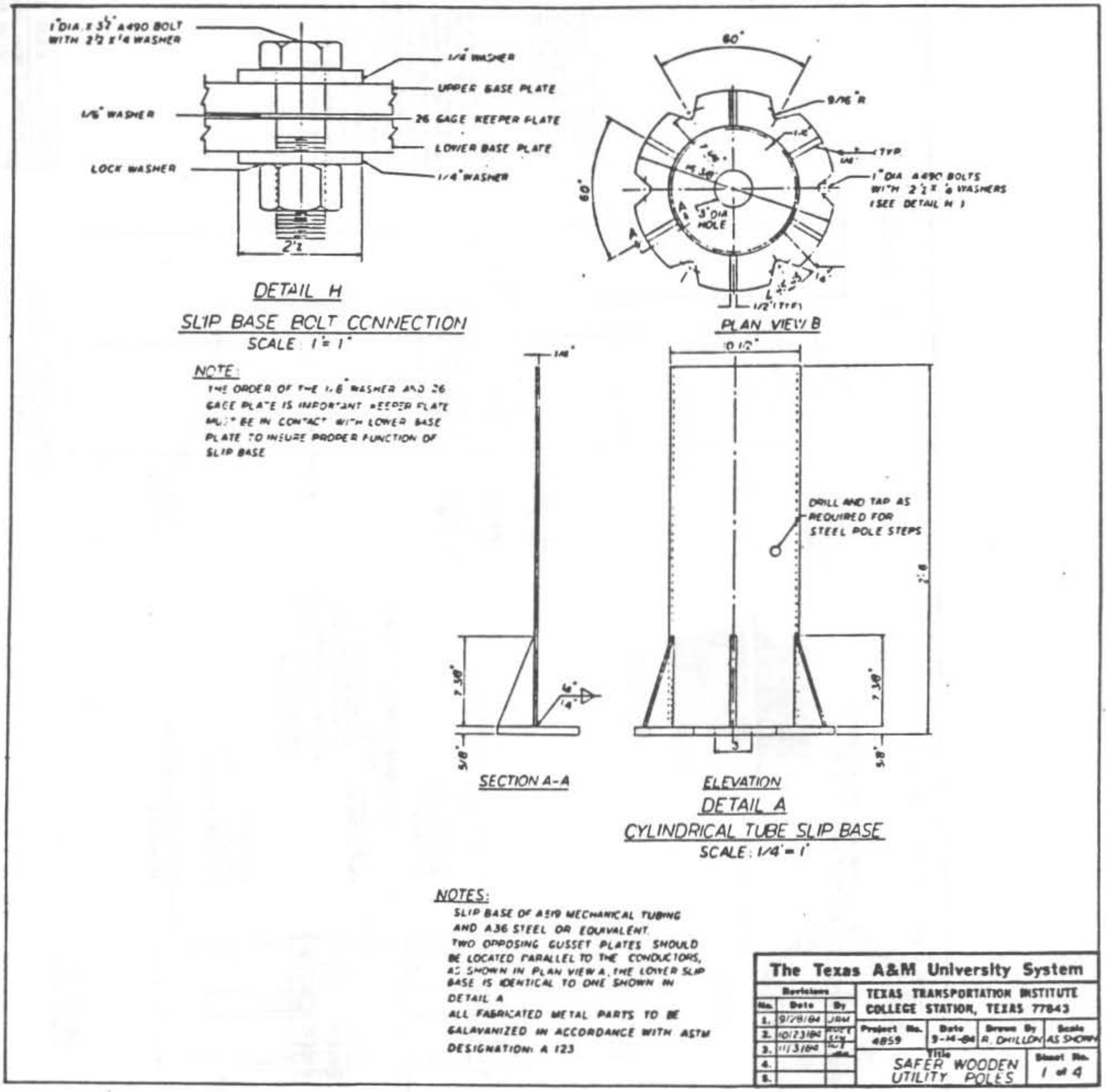
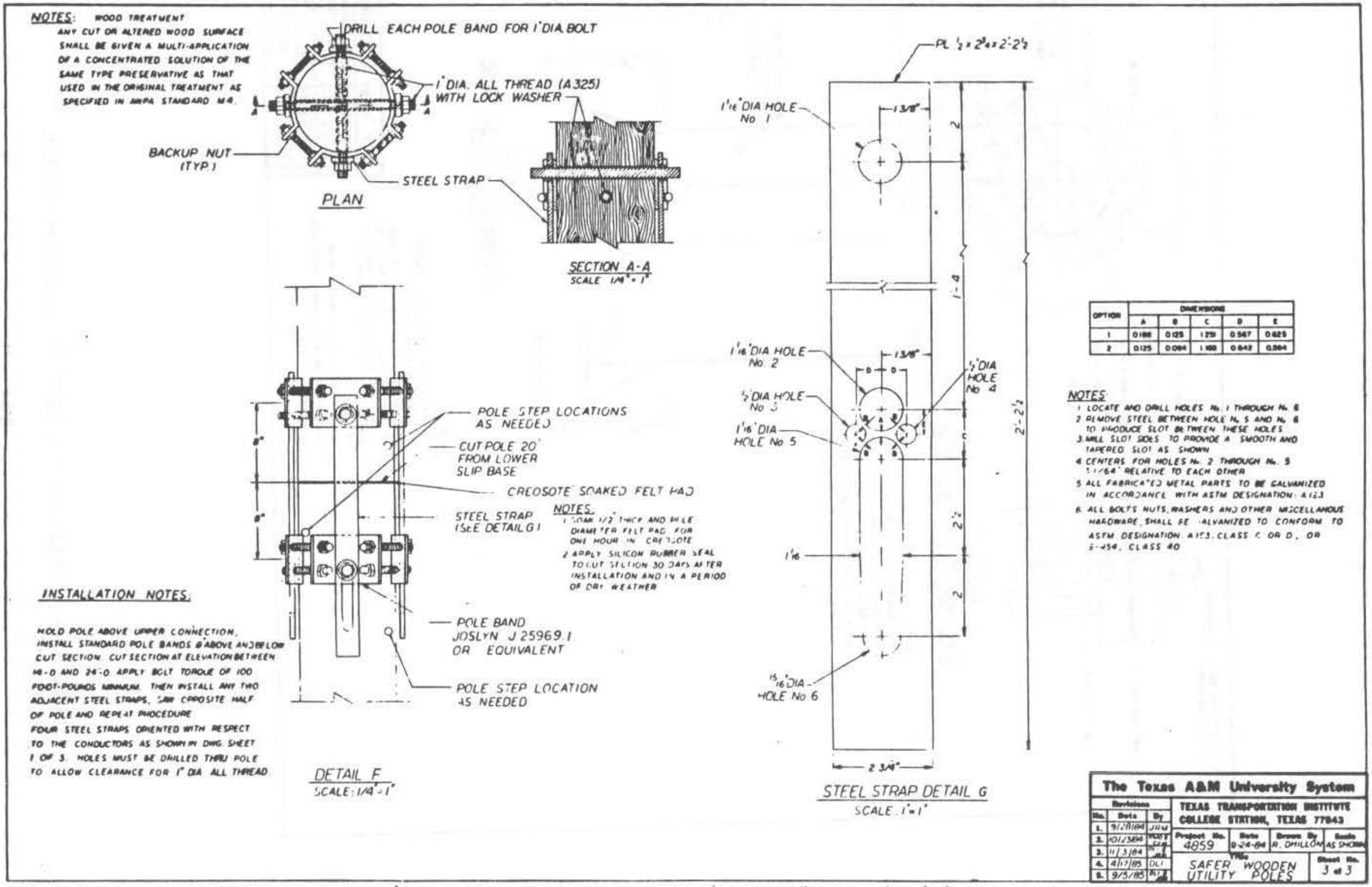


FIGURE I-4. DETAIL OF THE HAWKINS BREAKAWAY SYSTEM.



OPTION	DIMENSIONS				
	A	B	C	D	E
1	0.188	0.125	1.251	0.567	0.625
2	0.125	0.094	1.188	0.642	0.984

FIGURE I-5. DETAIL OF THE HAWKINS BREAKAWAY SYSTEM (cont'd).

A number of major conclusions were obtained from the results of crash tests conducted on the HBS (43). In collisions at speeds between 20 to 60 mph with vehicles between 1800 and 4300 lb. gross vehicle weight, the average probability of severe injury [abbreviated injury scale (AIS) > 3] had been reduced by 91%. In collisions at speeds between 40 to 60 mph, the probability of severe injury has been reduced by 97%. These reductions are far in excess of what most researchers considered probable. Zeeger and Cynecki used example values of 30 and 60% reduction in injury and fatal accidents in their benefit-to-cost studies for the FHWA (18).

Although the 60% value may not be unreasonable if AIS injuries of 1 are considered, it appears that injuries would be considerably biased toward the minor and moderate injury levels (AIS levels 1 and 2) (43). It was still thought that Zegeer's and Cynecki's use of the 60% overall injury and total accident reduction may still be too low when accident costs were determined for the HBS. Thus, the HBS would be cost-effective in a wider variety of situations than was originally predicted.

APPENDIX J

CALCULATION OF ROADSIDE COVERAGE FACTOR AND AVERAGE LATERAL OFFSET OF THE FIXED OBJECTS

Page

SITE #1

CALCULATIONS

"O" ST. FROM 27th TO 48th

	Segment Length (ft.)	SIDE #1 (South Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 (North Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR
1	0 - 200	3	10.67	—	—	50%	8	13.25	109	16.00	100%	75%
2	200 - 400	—	—	—	—	0%	3	11.67	27	16.00	85%	42.5%
3	400 - 600	2	11.00	—	—	35%	—	—	—	—	0%	17.5%
4	600-800	1	16.00	—	—	19%	1	12.00	—	—	19%	19%
5	800 - 1000	2	7.00	22	18.00	70%	2	11.00	—	—	35%	52.5%
6	1000-1200	2	9.50	19	18.00	70%	2	16.00	—	—	35%	52.5%
7	1200-1400	1	11.00	—	—	19%	3	9.33	—	—	50%	34.5%
8	1400-1600	1	16.00	—	—	19%	1	7.00	—	—	19%	19%
9	1600-1800	3	10.67	40	18.00	85%	3	15.67	—	—	50%	67.5%
10	1800-2000	2	9.00	—	—	35%	5	14.80	—	—	77%	56%
11	2000-2200	2	12.00	—	—	35%	2	13.00	40.5	14.00	70%	52.5%
12	2200-2400	—	—	—	—	0%	2	14.50	16	14.00	70%	35%
13	2400-2600	1	10.00	—	—	19%	1	11.00	—	—	19%	19%
14	2600-2800	4	13.50	—	—	64%	4	10.75	87	7.00	100%	82%
15	2800-3000	5	10.00	—	—	77%	3	11.00	11	7.00	85%	81%
16	3000-3200	2	8.00	142	7.00	100%	5	11.60	140	7.00	100%	100%
17	3200-3400	1	15.00	18	7.00	54%	1	9.00	10	8.00	38%	46%
18	3400-3600	1	13.00	—	—	19%	—	—	200	7.00	100%	59.5%
19	3600-3800	1	11.00	—	—	19%	3	10.33	100	10.00	100%	59.5%
20	3800-4000	—	—	—	—	0%	3	6.33	41	5.00	85%	42.5%
21	4000-4200	4	9.50	114	7.00	100%	—	—	200	6.00	100%	100%
22	4200-4400	3	7.00	153	7.00	100%	—	—	200	6.00	100%	100%
23	4400-4600	1	7.00	165	7.00	100%	—	—	200	6.00	100%	100%

10/24/89 RF

DataCom / Made in U.S.A.

"O" ST. FROM 27th TO 48th

	Segment Length (ft.)	SIDE #1 (South Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 (North Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR	
24	4600-4800	—	———	200	7.00	100%	—	———	200	6.00	100%	100%	
25	4800-5000	2	14.00	157	7.00	100%	—	———	200	6.00	100%	100%	
26	5000-5200	1	9.00	200	9.50	100%	—	———	200	6.00	100%	100%	
27	5200-5400	1	10.00	57.5	12.00	69%	—	———	200	6.00	100%	84.5%	
28	5400-5600	2	10.00	100	12.00	99%	—	———	200	6.00	100%	99.5%	
29	5600-5800	3	8.33	32	9.50	85%	—	———	200	6.00	100%	92.5%	
30	5800-6000	3	12.00	39.5	7.50	85%	1	12.00	26	7.50	54%	69.5%	
31	6000-6200	5	9.20	133	7.00	100%	1	16.00	—	———	19%	59.5%	
32	6200-6400	3	11.33	24.5	6.50	85%	1	15.00	—	———	19%	52%	
33	6400-6600	3	9.00	92	7.00	100%	1	17.00	—	———	19%	59.5%	
34	6600-6800	—	———	75	7.00	50%	1	16.00	—	———	19%	34.5%	
35	6800-7000	1	19.00	40	11.00	54%	2	10.50	—	———	35%	44.5%	
36	7000-7200	1	13.00	—	———	19%	1	12.00	—	———	19%	19%	
37	7200-7400	2	11.00	6	7.00	54%	2	9.00	22	12.00	70%	62%	
38	7400-7600	—	———	200	7.00	100%	3	10.33	28	12.00	85%	92.5%	
39	7600-7800	—	———	48.5	8.50	35%	—	———	38.5	15.00	35%	35%	Σ2417.5
39.2*	7800-7840	1	9.00	13	10.00	54%	—	———	—	———	0%	27%	Σ2444.5
	Σ	70	736.98	2091	17250.75		65	779.99	2696	19490.5		61.8%**	
			Ave.=10.53	$\bar{x}$=9.39	Ave.=8.25			Ave.=12.00	$\bar{x}$=9.62	Ave.=7.23			
										$\frac{200(2417.5)+40(27)}{7840}$		=61.81%	
							Ave. Offset=		9.51'**				

* START OF 48th ST. (WEST SIDE OF STREET)(AT 7840')

10/24/89 RF

"O" ST. FROM 48th TO 63rd

	Segment Length (ft.)	SIDE #1 (South Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 (North Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR	
26.3*	7840–8000	—	—	—	—	0%	2	15.00	—	—	35%	17.5%	≤17.5
1	8000–8200	1	7.00	180	8.00	100%	2	10.00	—	—	35%	67.5%	
2	8200–8400	—	—	162	8.00	100%	2	11.00	42	9.00	70%	85%	
3	8400–8600	1	13.00	116	8.00	96%	1	19.00	133	9.00	100%	98%	
4	8600–8800	2	16.50	94.5	7.33	99%	—	—	94	9.00	64%	81.5%	
5	8800–9000	1	7.00	105	7.00	96%	—	—	149	8.00	89%	92.5%	
6	9000–9200	2	8.00	62	8.50	85%	1	13.00	26	7.00	54%	69.5%	
7	9200–9400	3	14.00	79	10.50	100%	1	16.00	—	—	19%	59.5%	
8	9400–9600	6	9.33	5	12.00	100%	2	13.50	17.5	19.00	70%	85%	
9	9600–9800	3	12.33	29	12.00	85%	4	10.00	94.5	14.00	100%	92.5%	
10	9800–10000	5	13.00	44	14.00	100%	1	9.00	—	—	19%	59.5%	
11	10000–10200	3	14.00	44	9.00	85%	1	11.00	72	7.00	69%	77%	
12	10200–10400	3	19.33	—	—	50%	2	7.00	63	12.00	85%	67.5%	
13	10400–10600	3	19.00	—	—	50%	6	15.33	—	—	89%	69.5%	
14	10600–10800	1	12.00	75	9.00	69%	4	12.75	22.5	15.00	99%	84%	
15	10800–11000	1	9.00	95	9.00	83%	1	10.00	42.5	10.00	54%	68.5%	
16	11000–11200	3	10.00	—	—	50%	2	15.50	—	—	35%	42.5%	
17	11200–11400	6	12.83	—	—	89%	2	16.00	—	—	35%	62%	
18	11400–11600	1	19.00	—	—	19%	1	15.00	—	—	19%	19%	
19	11600–11800	—	—	13.5	8.00	35%	1	14.00	—	—	19%	27%	
20	11800–12000	—	—	100	8.00	64%	1	12.00	—	—	19%	41.5%	
21	12000–12200	1	10.00	50	8.00	54%	1	12.00	—	—	19%	36.5%	
22	12200–12400	2	11.50	66	9.00	85%	—	—	—	—	0%	42.5%	

"O" ST. FROM 48^{th} TO 63^{rd}

	Segment Length (ft.)	SIDE #1 (South Side) Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	SIDE #2 (North Side) Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR	
23	12400–12600	3	13.67	7.5	14.00	69%	2	14.00	—	—	35%	52%	
24	12600–12800	—	—	35	14.00	35%	2	16.00	—	—	35%	35%	
25	12800–13000	—	—	—	—	0%	2	8.50	—	—	35%	17.5%	
26	13000–13200	3	8.00	—	—	50%	1	10.00	—	—	19%	34.5%	Σ 1567
	Σ	54	677.85	1362.5	11895.18		45	576.98	756	7473		58.7% **	
			Ave. = 12.55	$\bar{x}$ = 10.64	Ave. = 8.73			Ave. = 12.82	$\bar{x}$ = 11.35	Ave. = 9.88			

Ave. Offset = 11.00' **

Determination of Lengths:
0–7840': Section #1 – 7840'
7840–13200': Section #2 – 5360'

$\frac{200(1567) + 60(17.5)}{(13200 - 7840)} = 58.67\%$

FINAL COVERAGE FACTOR: $\frac{7840(61.8\%) + 5360(58.7\%)}{13200} = 60.5\%$

FINAL FIXED OBJECT: AVERAGE LATERAL OFFSET: $\frac{7840(9.57') + 5360(11.00')}{13200} = 10.12'$

SITE #2

CALCULATIONS

WAYNE, NEBRASKA, ALONG SEVENTH ST. FROM SHERMAN TO MAIN

		SIDE #1 (South Side)					SIDE #2					TOTAL COVERAGE FACTOR
	Segment Length (ft.)	Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	
1	0 – 200	2	6.00	——	——	35%						
2	200 – 400	5	14.80	——	——	77%						
3	400 – 600	4	8.50	41	3.00	99%						
4	600 – 800	2	9.00	——	——	35%						
5	800 – 1000	3	9.00	——	——	50%						
6	1000 – 1200	5	12.40	——	——	77%						
7	1200 – 1400	3	8.67	——	——	50%						
8	1400 – 1600	3	19.00	——	——	50%						
9	1600 – 1800	3	10.00	19	10.00	85%						
10	1800 – 2000	——	——	14	17.00	35%						
	Σ	30	340.01	74	551	59.3% **						
			Ave. = 11.33	x̄ = 9.39	Ave = 7.45							

FIXED OBJECT COVERAGE FACTOR: 59.3%

FIXED OBJECT AVERAGE LATERAL OFFSET: 9.39 ft.

10/31/89 RF

SITE #3

CALCULATIONS

WAYNE, NEBRASKA, ALONG SEVENTH ST. FROM NEBRASKA⁻ TO WALNUT⁺

	Segment Length (ft.)	SIDE #1 (South Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 (North Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR
1	0–200	3	9.33	—	—	50%	1	17.00	—	—	19%	34.5%
2	200–400	2	14.50	—	—	35%	8	6.50	—	—	100%	67.5%
3	400–600	2	8.00	—	—	35%	6	10.33	—	—	89%	62.0%
4	600–800	4	8.50	—	—	64%	5	8.20	—	—	77%	70.5%
5	800–1000	1	4.00	—	—	19%	8	7.00	—	—	100%	59.5%
6	1000–1200	3	10.00	—	—	50%	3	7.00	—	—	50%	50.0%
7	1200–1400	2	12.00	—	—	35%	6	8.50	—	—	89%	62.0%
	Σ	17	164.99	0	0		37	299.98	0	0		58.0%**
			Ave. = 9.71		$\bar{X}$ = 9.71			Ave. = 8.11		$\bar{X}$ = 8.11		

Average = $\frac{9.71 + 8.11}{2}$ = 8.91'**

FIXED OBJECT COVERAGE FACTOR: 58.0%

FIXED OBJECT AVERAGE LATERAL OFFSET: 8.91 ft.

10/31/89 RF

SITE #4

CALCULATIONS

DataCom / Made in U.S.A.

(AFTER) **Florence Blvd.**
6/13/90

Speed Limit = 35 mph (One-Way Roadway)
3-Lane: 30' (4-6 p.m.)
1-Shoulder Lane: 9'

Start: Cuming St. to Lake St.

	Segment Length (ft.)	SIDE #1 (East Side) Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	SIDE #2 (West Side) Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR
1	0–200	4	10.75	146	10.00	100%	2	10.50	127	13.67	100%	100%
2	200–400	3	4.00	112	13.00	100%	3	2.67	125	19.00	100%	100%
3	400–600	3	8.00	120	19.00	100%	3	5.67	100	20.00	100%	100%
4	600–800	2	4.00	—	—	35%	3	10.33	—	—	50%	42.5%
5	800–1000	2	15.50	—	—	35%	—	—	70	13.00	50%	42.5%
6	1000–1200	2	13.00	—	—	35%	—	—	146	12.50	89%	62%
7	1200–1400	2	12.00	26	12.00	70%	5	12.40	—	—	77%	73.5%
8	1400–1600	—	—	177	9.00	100%	—	—	—	—	0%	50%
9	1600–1800	—	—	188	6.00	100%	1	11.00	—	—	19%	59.5%
10	1800–2000	2	6.50	—	—	35%	1	9.00	—	—	19%	27%
11	2000–2200	7	11.14	—	—	100%	—	—	—	—	0%	50%
12	2200–2400	—	—	139	11.00	89%	3	11.00	—	—	50%	69.5%
13	2400–2600	1	6.00	161	12.00	100%	2	13.00	—	—	35%	67.5%
14	2600–2800	2	14.00	4	12.00	54%	2	10.50	—	—	35%	44.5%
15	2800–3000	2	13.00	97	12.00	99%	3	11.67	25	11.00	85%	92%
16	3000–3200	2	9.50	—	—	35%	4	15.00	—	—	64%	49.5%
17	3200–3400	1	20.00	—	—	19%	—	—	—	—	0%	9.5%
18	3400–3600	1	11.00	—	—	19%	3	14.33	—	—	50%	34.5%
19	3600–3800	—	—	7	8.00	19%	1	9.00	40	12.00	54%	36.5%
20	3800–4000	—	—	23	8.00	35%	2	14.50	67	12.00	85%	60%
21	4000–4200	1	16.00	—	—	19%	9	11.78	—	—	100%	59.5%
22	4200–4400	1	14.00	—	—	19%	4	13.00	—	—	64%	41.5%
23	4400–4600	3	13.00	—	—	50%	2	18.00	—	—	35%	42.5%

DataCom / Made in U.S.A.

Florence Blvd.
6/13/90

Start: Cuming St. to Lake St. (AFTER)

Segment Length (ft.)	SIDE #1 (East Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 (West Side) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR	
24 4600–4800	4	16.25	23	19.00	99%	4	12.00	——	——	64%	81.5%	Σ1378 Σ1395.5
25 4800–4900	1	16.00	——	——	19%	1	17.00	——	——	19%	19%	Σ1397 Σ1414.5
											~~56.63%~~ **	
Σ	46	518.98	1223	13,579		58	674.00	700	10,405.09		57.34	
		Avg. = 11.28		Avg. = 11.10			Avg. = 11.62		Avg. = 14.86			
			$\bar{x}$ = 11.19					$\bar{x}$ = 13.24				

Ave. Offset = 12.22' **

FIXED OBJECT COVERAGE FACTOR: 57.34% ~~56.63%~~

FIXED OBJECT AVERAGE LATERAL OFFSET: 12.22'

$\frac{200(1378)\ 1395.5 + 100(19)}{4900}$ = 57.34 ~~56.63%~~

SITE #5

CALCULATIONS

DataCom / Made in U.S.A.

36th ST.

7/12/90
RF

Edward Babe Gomez St. to "R" St.+ BEFORE

Segment Length (ft.)	SIDE #1 Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 (WEST SIDE) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR
1 0 - 200						1	20.0	—	—	19.0%	
2 200 - 400						4	11.75	42	11.5	99.0%	
3 400 - 600		East Side Numbers				—	—	40	13.0	35.0%	
4 600 - 800		Could Be Used With				3	6.67	—	—	50%	
5 800 - 1000		Tree Removals To				9	10.22	—	—	100%	
6 1000 - 1200		Determine The				8	11.25	32	9.0	100%	
7 1200 - 1400		Before Case Of CF.				2	2.0	—	—	35%	
8 1400 - 1600						—	—	—	—	0%	
9 1600 - 1800						2	10.5	17	11.0	70%	
10 1800 - 2000						1	9.0	136	13.67	100%	
11 2000 - 2200						3	8.0	50	17.0	85%	
						33	9.91	317	13.21	63%	
							$327.00		$4187.12	$693 11÷	
							$\bar{x} = \frac{9.91 + 13.21}{2} = $			11.56'	

FIXED OBJECT COVERAGE FACTOR: 63.00%

FIXED OBJECT AVERAGE LATERAL OFFSET: 11.56'

DataCom / Made in U.S.A.

36th ST.
6/15/90

Speed Limit = 30mph (Two-Way Roadway)
2-Lane : 28'
3-Lane : 37'

Edward Babe Gomez St. to "R" St.+

AFTER

	Segment Length (ft.)	SIDE #1 (EAST SIDE) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR
1	0 – 200	3	20.00	——	——	50%						
2	200 – 400	4	14.00	——	——	64%						
3	400 – 600	1	9.00	——	——	19%			West Side Numbers			
4	600 – 800	0	——	16	15.50	35%			Used With Tree			
5	800 – 1000	1	20.00	66	16.00	69%			Removals To Determine			
6	1000 – 1200	3	14.33	67	16.00	100%			C_F In Before Case.			
7	1200 – 1400	2	17.00	37	16.00	70%						
8	1400 – 1600	0	——	4	16.00	19%						
9	1600 – 1800	2	16.50	23	16.00	70%						
10	1800 – 2000	2	6.00	——	——	35%						
11	2000 – 2200	3	12.00	42	14.00	85%	Σ616					
	Σ	21	303.00	255	3,988	56.00%**						
			Avg. = 14.43		Avg. = 15.64							
			$\bar{X}$ = 15.04'**									

FIXED OBJECT COVERAGE FACTOR: 56.00%

FIXED OBJECT AVERAGE LATERAL OFFSET: 15.04'

SITE #6

CALCULATIONS

DataCom / Made in U.S.A.

6/19/90
RF

WEST "O" ST. — CAPITOL BLVD. TO STATION 211+00

	Segment Length (ft.)	SIDE #1 (SOUTH SIDE) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	SIDE #2 (NORTH SIDE) Point Objects #	Ave. Offset (ft.)	Continuous Objects Length (ft.)	Ave. Offset (ft.)	Coverage Factor	TOTAL COVERAGE FACTOR	
1	177+00-179+00	1	20.0	—	—	19.0%	3	10.33	—	—	50%	34.5%	
2	179 -181	1	12.0	—	—	19.0%	—	—	—	—	0%	9.5%	
3	181 -183	—	—	—	—	0%	—	—	90.0	13.0	64%	32.0%	
4	183 -185	—	—	—	—	0%	1	16.0	86.0	14.0	83%	41.5%	
5	185 -187	—	—	—	—	0%	1	16.0	25.0	15.0	54%	27.0%	
6	187 -189	1	12.0	—	—	19%	1	15.0	—	—	19%	19.0%	
7	189 -191	—	—	—	—	0%	1	16.0	—	—	19%	9.5%	
8	191 -193	—	—	—	—	0%	—	—	20.0	17.0	35%	17.5%	
9	193 -195	1	13.0	—	—	19%	—	—	—	—	0%	9.5%	
10	195 -197	—	—	—	—	0%	1	19.0	—	—	19%	9.5%	
11	197 -199	—	—	—	—	0%	1	9.0	—	—	19%	9.5%	
12	199 -201	—	—	—	—	0%	—	—	—	—	0%	0%	
13	201 -203	1	15.0	—	—	19%	—	—	50.0	1.0	35%	27%	
14	203 -205	—	—	—	—	0	—	—	60.0	1.0	50%	25%	
15	205 -207	—	—	—	—	0	—	—	—	—	0%	0%	
16	207 -209	1	8.0	—	—	19%	—	—	—	—	0%	9.5%	
17	209 -211	2	12.5	—	—	35%	—	—	—	—	0%	17.5%	Σ298
	Σ	8	105.0	0	0		9	122.0	331	3,199		17.53%	
			Avg.=13.125'					Avg.=13.56'		Avg.=9.66'			
									x̄=11.61'				
						MEAN =		(11.61+13.12)/2	= 12.36'				

FIXED OBJECT COVERAGE FACTOR = 17.53%

FIXED OBJECT AVERAGE LATERAL OF[illegible]E[illegible] = 1[illegible] 36'

SITE #7

CALCULATIONS

WEST "O" ST. — STATION 211+00 TO STATION 241+00 (N. 3rd ST.)

6/20/90 RF

		SIDE #1 (SOUTH SIDE)					SIDE #2 (NORTH SIDE)					TOTAL COVERAGE FACTOR
	Segment Length (ft.)	Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	Point Objects #	Point Objects Ave. Offset (ft.)	Continuous Objects Length (ft.)	Continuous Objects Ave. Offset (ft.)	Coverage Factor	
1	211+00–213+00	—	—	—	—	0%	—	—	—	—	0%	0%
2	213 – 215	—	—	—	—	0%	—	—	—	—	0%	0%
3	215 – 217	1	10.0	—	—	19%	1	14.0	—	—	19%	19%
4	217 – 219	1	5.0	—	—	19%	—	—	—	—	0%	9.5%
5	219 – 221	—	—	—	—	0%	1	3.0	—	—	19%	9.5%
6	221 – 223	—	—	—	—	0%	—	—	—	—	0%	0%
7	223 – 225	—	—	95'	1.0	64%	—	—	90'	1'	64%	64%
8	225 – 227	—	—	117'	1.0	77%	2	10.5	120'	1.583'	100%	88.5%
9	227 – 229	—	—	—	—	0%	1	3.0	—	—	19%	9.5%
10	229 – 231	—	—	—	—	0%	—	—	—	—	0%	0%
11	231 – 233	4	13.0	—	—	64%	1	3.0	—	—	19%	41.5%
12	233 – 235	—	—	—	—	0%	—	—	—	—	0%	0%
13	235 – 237	1	9.0	—	—	19%	1	3.0	—	—	19%	19%
14	237 – 239	2	18.0	—	—	35%	—	—	—	—	0%	17.5%
15	239 – 241	5	12.4	—	—	77%	1	12.0	—	—	19%	48%
	Σ	14	174	182	182		Σ 8	59	210	279.96		21.73%
			Avg. = 12.43'		Avg. = 1.0'			Avg. = 7.38'		Avg. = 1.331'		
				$\bar{x}$ = 6.72'					$\bar{x}$ = 4.36'			

$$MEAN = \frac{6.72' + 4.36'}{2} = 5.54'$$

FIXED OBJECT COVERAGE FACTOR = 21.73%

FIXED OBJECT AVERAGE LATERAL

L. S. = [illegible]

APPENDIX K.

TYPICAL COST DATA FOR VARIOUS POLE INSTALLATIONS

Once the initial computer analyses had been completed on the individual sites, it was determined that the relocation costs were not typical. Thus, two local public utility companies, Lincoln Electric System (LES) and Omaha Public Power District (OPPD), and the Nebraska Department of Roads (NDOR) were consulted to obtain typical relocation costs for various pole installation types.

Since the relocation costs of the utilities was very much dependent upon the type of utility installation, it was necessary to try to categorize the different types of pole installations with the typical associated relocation costs. The utility installation type consisted of four major categories. They are as follows:

1. Basic Street Light Circuitry
2. Power Distribution
3. Power Transmission
4. Transmission Plus Distribution Underbuilt

These four categories were also broken down into more detail when necessary, as shown in Table K-1.

Photographs have been presented in Figures K-1 through K-6 to give a better understanding for some of the various typical utility and light pole installations located along roadways. They could be used as a guidance tool when making a initial field site visit for estimating initial relocation costs.

TABLE K-1.

Typical Relocation Costs for Various Utility Installations

Utility Installation Type		Typical Spacing (ft)	Average Relocation Cost Per Pole
1. Basic Street Light Circuitry		150'	$650
2. Power Distribution			
(a)	Local (Residential) 1-phase 4-13.8KV Wood Poles	100'	$1,650
(b)	Large Distribution 3-phase 4-13.8KV Wood Poles	100'	$1,700
(c)	Large Distribution (Feeder) Heavy 3-phase 4-13.8KV Wood Poles	100'	$3,500
3. Power Transmission			
(a)	35-69 KV	300'	
	Wood Poles		$8,350
	Steel Poles		$13,850
(b)	115-161 KV Steel Poles	300'	$27,100
4. Transmission Plus Distribution Underbuilt			
(a)	35 KV Wood Poles	300'	$15,850
(b)	115 KV Steel Poles	300'	$30,600

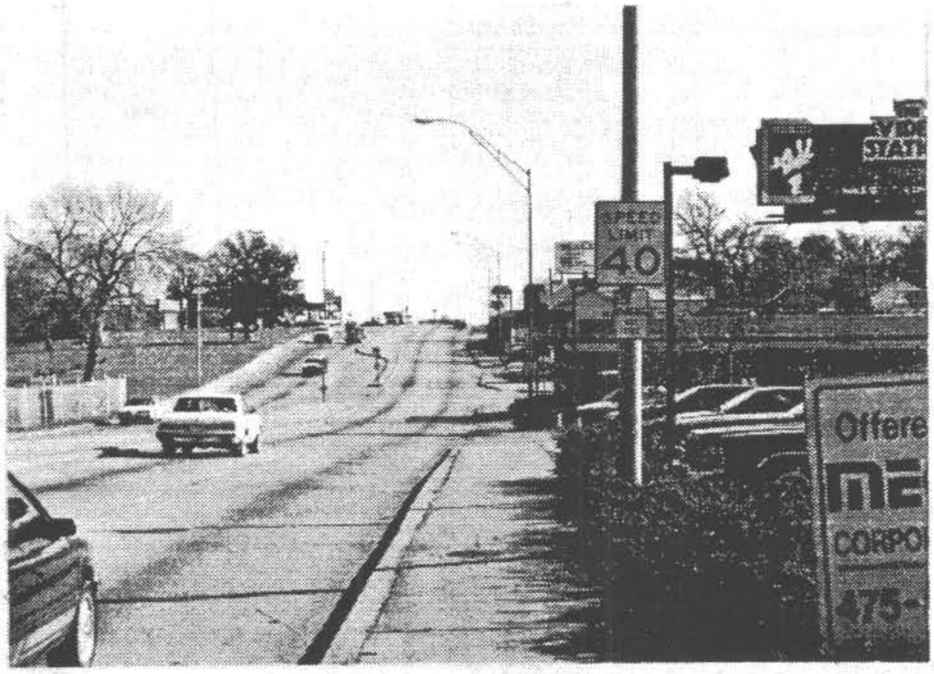


FIGURE K-1. PHOTOGRAPHS OF BASIC STREET LIGHT CIRCUITRY.

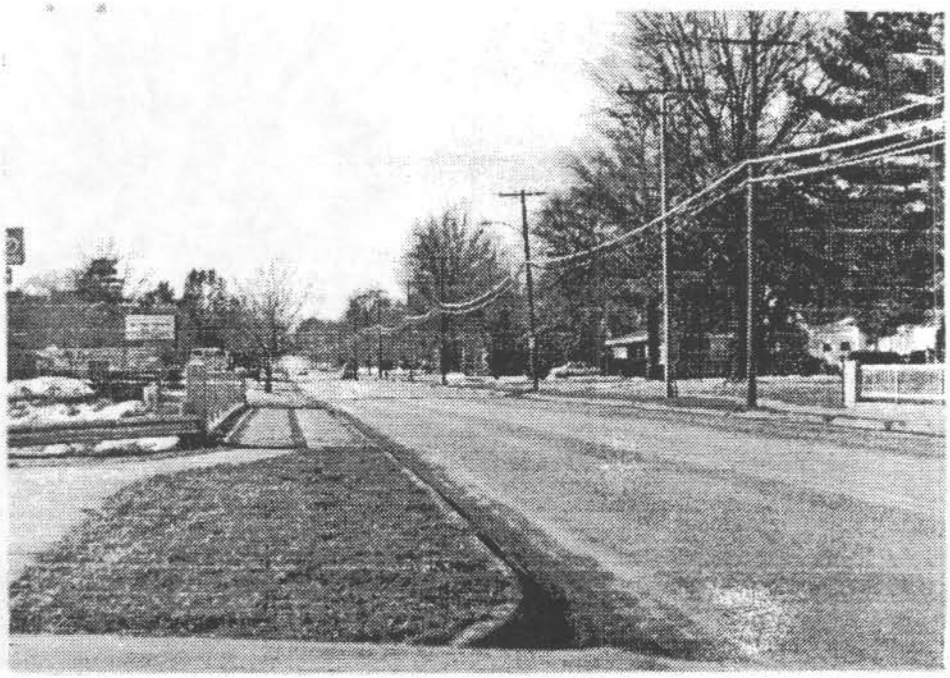


FIGURE K-2. PHOTOGRAPHS OF POWER DISTRIBUTION (12KV).

FIGURE K-3. PHOTOGRAPHS OF POWER TRANSMISSION (35KV, TOP) AND POWER DISTRIBUTION (12KV, BOTTOM).

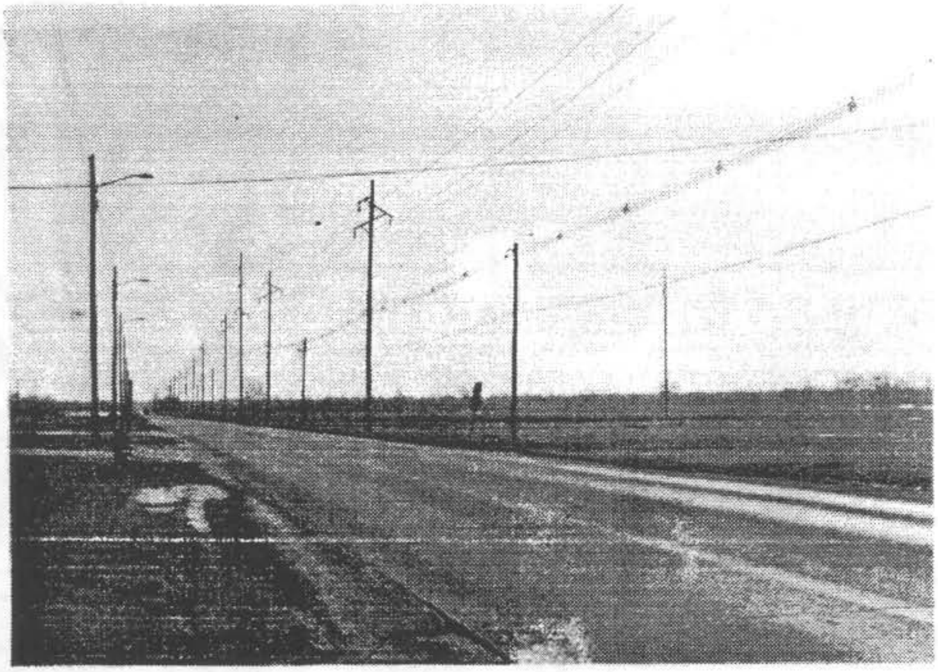


FIGURE K-4. PHOTOGRAPHS OF POWER TRANSMISSION (35KV, TOP) AND POWER DISTRIBUTION (12KV, BOTTOM) WITH ATTACHED CABLE TV.

FIGURE K-5. PHOTOGRAPHS OF POWER TRANSMISSION (115KV, TOP) AND POWER DISTRIBUTION (12KV, BOTTOM).

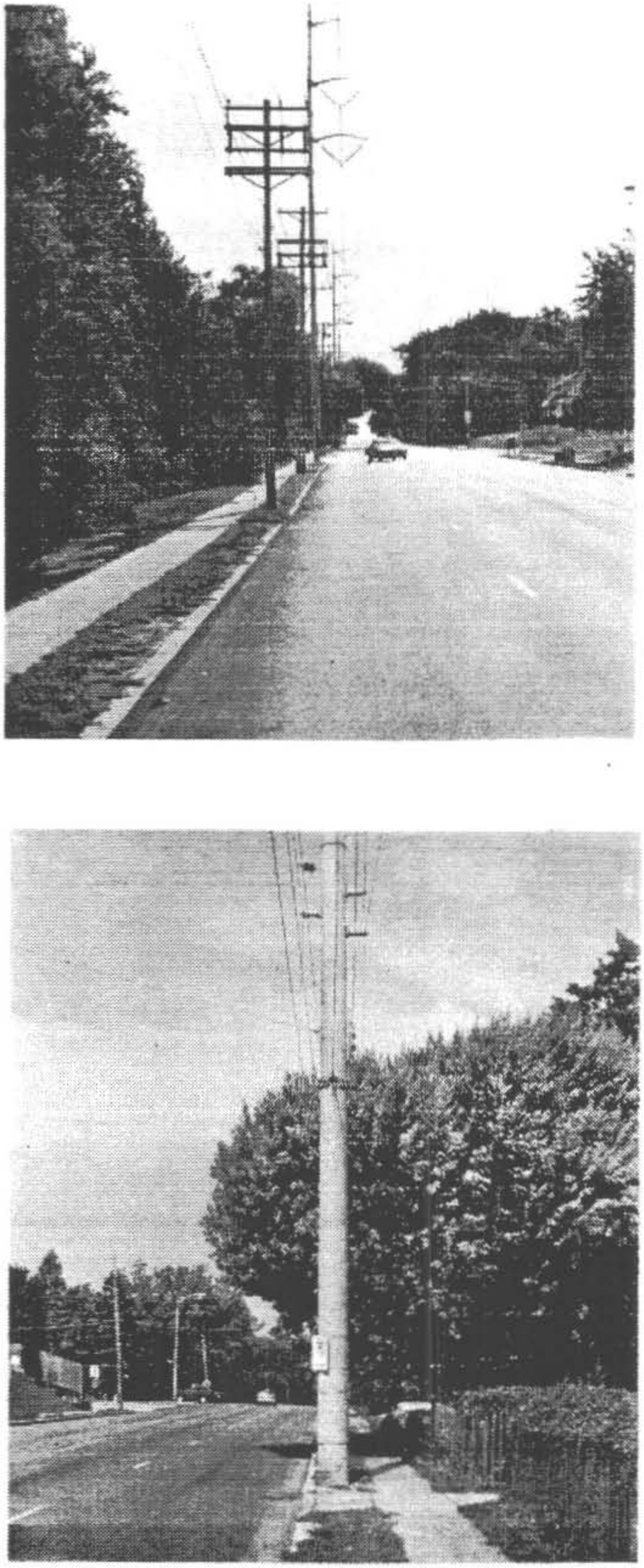


FIGURE K-6. PHOTOGRAPHS OF POWER TRANSMISSION (161KV).

APPENDIX L

EXAMPLE UPACE COMPUTER PRINTOUTS

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

SECTION CHARACTERISTICS

Basic Street Lighting (ADT = 40,000)

$650 x 72 = $46,800 total cost

10,560 / 150' = 70.4 ≈ 71 spaces

Use 72 poles

SEGMENT

BEG. MILEPOST:	.00	END MILEPOST:	2.00
LENGTH (MILES):	2.00		

ROADWAY

ROAD ALIGNMENT:	TANGENT	SHOULDER TYPE:	CURBED
NUMBER OF LANES:	4	RIGHT-OF-WAY WIDTH:	60 FT
ROAD WIDTH:	48.0 FT	TRAFFIC FLOW:	TWO-WAY
TERRRAIN:	FLAT	AREA TYPE:	URBAN
PAVEMENT:	CONCRETE	ROADSIDE COVERAGE:	.60
SIDE SLOPE:	FILL 10:1	OBJECTS LINE:	9 FT
HINGE LINE:	20 FT	OBSTRUCTED ZONE:	20 FT

UTILITY POLES

POLE CONFIGURATION:	ONE SIDE	POLE TYPE:	METAL
NUMBER OF POLES:	72	POLE USE:	
POLE OFFSET:	2 FT	LINE TYPE:	69KV 1 PHASE

TRAFFIC

SPEED LIMIT:	40. MPH	GROWTH FACTOR CODE:	1
BASE YEAR ADT:	40000. VEH	GROWTH RATE(%):	2.00

UTILITY POLE ACCIDENTS PER YEAR

TOTAL ACCIDENTS:	6.80	FATAL ACCIDENTS:	.07(1.0%)
INJURY ACCIDENTS:	3.15(46.3%)	PROPERTY DAMAGE:	3.58(52.7%)
FATALITIES:	.07	FATALITIES/FATAL ACC:	1.08
INJURIES:	4.17	INJURIES/FATAL ACC:	.70
INJURIES/INJURY ACC:	1.31		

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

DATA PROJECTIONS SUMMARY FOR SECTION

YEAR	ADT	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	40000.	1.00	6.795	.068	3.146	3.581	.073	4.169
2	40800.	1.00	6.899	.069	3.194	3.636	.075	4.233
3	41616.	1.00	7.005	.070	3.243	3.692	.076	4.298
4	42448.	1.00	7.113	.071	3.293	3.749	.077	4.364
5	43297.	1.00	7.223	.072	3.344	3.807	.078	4.432
6	44163.	1.00	7.336	.073	3.396	3.866	.079	4.501
7	45046.	1.00	7.450	.075	3.450	3.926	.080	4.571
8	45947.	1.00	7.567	.076	3.504	3.988	.082	4.643
9	46866.	1.00	7.687	.077	3.559	4.051	.083	4.716
10	47804.	1.00	7.808	.078	3.615	4.115	.084	4.791
11	48760.	1.00	7.933	.079	3.673	4.180	.086	4.867
12	49735.	1.00	8.059	.081	3.731	4.247	.087	4.945
13	50730.	1.00	8.188	.082	3.791	4.315	.088	5.024
14	51744.	1.00	8.320	.083	3.852	4.385	.090	5.105
15	52779.	1.00	8.454	.085	3.914	4.455	.091	5.187
16	53835.	1.00	8.591	.086	3.978	4.528	.093	5.271
17	54911.	1.00	8.731	.087	4.043	4.601	.094	5.357
18	56010.	1.00	8.874	.089	4.109	4.677	.096	5.444
19	57130.	1.00	9.019	.090	4.176	4.753	.097	5.534
20	58272.	1.00	9.168	.092	4.245	4.831	.099	5.625
TOTALS			158.222	1.582	73.257	83.383	1.709	97.074

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 1 -- Increase offset from 2 to 3 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	3 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	5.310	.053	2.459	2.799	.057	3.258
2	1.00	5.392	.054	2.496	2.842	.058	3.308
3	1.00	5.475	.055	2.535	2.885	.059	3.359
4	1.00	5.560	.056	2.574	2.930	.060	3.411
5	1.00	5.646	.056	2.614	2.976	.061	3.464
6	1.00	5.734	.057	2.655	3.022	.062	3.518
7	1.00	5.824	.058	2.697	3.069	.063	3.573
8	1.00	5.916	.059	2.739	3.118	.064	3.630
9	1.00	6.009	.060	2.782	3.167	.065	3.687
10	1.00	6.105	.061	2.827	3.217	.066	3.746
11	1.00	6.202	.062	2.872	3.269	.067	3.805
12	1.00	6.302	.063	2.918	3.321	.068	3.866
13	1.00	6.403	.064	2.964	3.374	.069	3.928
14	1.00	6.506	.065	3.012	3.429	.070	3.992
15	1.00	6.611	.066	3.061	3.484	.071	4.056
16	1.00	6.719	.067	3.111	3.541	.073	4.122
17	1.00	6.828	.068	3.162	3.599	.074	4.189
18	1.00	6.940	.069	3.213	3.658	.075	4.258
19	1.00	7.054	.071	3.266	3.718	.076	4.328
20	1.00	7.171	.072	3.320	3.779	.077	4.399
TOTALS		123.709	1.237	57.277	65.195	1.336	75.899

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 1 -- Increase offset from 2 to 3 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.889
TOTAL ROADSIDE ACCIDENTS REDUCED:	30.68
NET PDO ACCIDENTS REDUCED:	15.44
NET FATALITIES PREVENTED:	.35
NET INJURIES PREVENTED:	19.34
TOTAL ACCIDENT SAVINGS:	368768.80

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	37559.90
BENEFIT-COST RATIO:	7.880

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 2 -- Increase offset from 2 to 4 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	4 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	4.456	.045	2.063	2.348	.048	2.734
2	1.00	4.524	.045	2.095	2.384	.049	2.776
3	1.00	4.594	.046	2.127	2.421	.050	2.819
4	1.00	4.666	.047	2.160	2.459	.050	2.863
5	1.00	4.738	.047	2.194	2.497	.051	2.907
6	1.00	4.813	.048	2.228	2.536	.052	2.953
7	1.00	4.888	.049	2.263	2.576	.053	2.999
8	1.00	4.965	.050	2.299	2.617	.054	3.046
9	1.00	5.044	.050	2.335	2.658	.054	3.095
10	1.00	5.124	.051	2.373	2.701	.055	3.144
11	1.00	5.206	.052	2.411	2.744	.056	3.194
12	1.00	5.290	.053	2.449	2.788	.057	3.245
13	1.00	5.375	.054	2.489	2.833	.058	3.298
14	1.00	5.462	.055	2.529	2.878	.059	3.351
15	1.00	5.551	.056	2.570	2.925	.060	3.405
16	1.00	5.641	.056	2.612	2.973	.061	3.461
17	1.00	5.733	.057	2.655	3.021	.062	3.518
18	1.00	5.827	.058	2.698	3.071	.063	3.575
19	1.00	5.923	.059	2.742	3.122	.064	3.634
20	1.00	6.021	.060	2.788	3.173	.065	3.694
TOTALS		103.843	1.038	48.079	54.725	1.122	63.711

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 2 -- Increase offset from 2 to 4 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.889
TOTAL ROADSIDE ACCIDENTS REDUCED:	48.34
NET PDO ACCIDENTS REDUCED:	24.33
NET FATALITIES PREVENTED:	.55
NET INJURIES PREVENTED:	30.47
TOTAL ACCIDENT SAVINGS:	581030.30

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	59179.21
BENEFIT-COST RATIO:	12.415

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 3 -- Increase offset from 2 to 5 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	5 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	3.888	.039	1.800	2.049	.042	2.385
2	1.00	3.947	.039	1.828	2.080	.043	2.422
3	1.00	4.009	.040	1.856	2.113	.043	2.459
4	1.00	4.071	.041	1.885	2.145	.044	2.498
5	1.00	4.135	.041	1.914	2.179	.045	2.537
6	1.00	4.199	.042	1.944	2.213	.045	2.576
7	1.00	4.266	.043	1.975	2.248	.046	2.617
8	1.00	4.333	.043	2.006	2.284	.047	2.659
9	1.00	4.402	.044	2.038	2.320	.048	2.701
10	1.00	4.472	.045	2.071	2.357	.048	2.744
11	1.00	4.544	.045	2.104	2.395	.049	2.788
12	1.00	4.617	.046	2.138	2.433	.050	2.833
13	1.00	4.691	.047	2.172	2.472	.051	2.878
14	1.00	4.767	.048	2.207	2.512	.051	2.925
15	1.00	4.845	.048	2.243	2.553	.052	2.973
16	1.00	4.924	.049	2.280	2.595	.053	3.021
17	1.00	5.005	.050	2.317	2.638	.054	3.071
18	1.00	5.087	.051	2.355	2.681	.055	3.121
19	1.00	5.171	.052	2.394	2.725	.056	3.173
20	1.00	5.257	.053	2.434	2.770	.057	3.225
TOTALS		90.630	.906	41.962	47.762	.979	55.604

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 3 -- Increase offset from 2 to 5 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.889
TOTAL ROADSIDE ACCIDENTS REDUCED:	60.08
NET PDO ACCIDENTS REDUCED:	30.24
NET FATALITIES PREVENTED:	.68
NET INJURIES PREVENTED:	37.87
TOTAL ACCIDENT SAVINGS:	722210.80

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	73558.75
BENEFIT-COST RATIO:	15.432

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 4 -- Increase offset from 2 to 6 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	6 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	3.476	.035	1.610	1.832	.038	2.133
2	1.00	3.530	.035	1.634	1.860	.038	2.166
3	1.00	3.585	.036	1.660	1.889	.039	2.199
4	1.00	3.641	.036	1.686	1.919	.039	2.234
5	1.00	3.698	.037	1.712	1.949	.040	2.269
6	1.00	3.756	.038	1.739	1.979	.041	2.304
7	1.00	3.815	.038	1.767	2.011	.041	2.341
8	1.00	3.876	.039	1.795	2.043	.042	2.378
9	1.00	3.938	.039	1.823	2.075	.043	2.416
10	1.00	4.001	.040	1.852	2.108	.043	2.454
11	1.00	4.065	.041	1.882	2.142	.044	2.494
12	1.00	4.130	.041	1.912	2.177	.045	2.534
13	1.00	4.197	.042	1.943	2.212	.045	2.575
14	1.00	4.265	.043	1.975	2.248	.046	2.617
15	1.00	4.335	.043	2.007	2.284	.047	2.659
16	1.00	4.406	.044	2.040	2.322	.048	2.703
17	1.00	4.478	.045	2.073	2.360	.048	2.747
18	1.00	4.552	.046	2.107	2.399	.049	2.793
19	1.00	4.627	.046	2.142	2.438	.050	2.839
20	1.00	4.704	.047	2.178	2.479	.051	2.886
TOTALS		81.073	.811	37.537	42.725	.876	49.741

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 4 -- Increase offset from 2 to 6 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.889
TOTAL ROADSIDE ACCIDENTS REDUCED:	68.58
NET PDO ACCIDENTS REDUCED:	34.52
NET FATALITIES PREVENTED:	.78
NET INJURIES PREVENTED:	43.23
TOTAL ACCIDENT SAVINGS:	824327.00

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	83959.51
BENEFIT-COST RATIO:	17.614

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 5 -- Increase offset from 2 to 7 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	7 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	3.162	.032	1.464	1.666	.034	1.940
2	1.00	3.211	.032	1.487	1.692	.035	1.970
3	1.00	3.261	.033	1.510	1.719	.035	2.001
4	1.00	3.312	.033	1.534	1.745	.036	2.032
5	1.00	3.364	.034	1.558	1.773	.036	2.064
6	1.00	3.417	.034	1.582	1.801	.037	2.097
7	1.00	3.471	.035	1.607	1.829	.037	2.130
8	1.00	3.526	.035	1.633	1.858	.038	2.164
9	1.00	3.583	.036	1.659	1.888	.039	2.198
10	1.00	3.640	.036	1.685	1.918	.039	2.233
11	1.00	3.699	.037	1.712	1.949	.040	2.269
12	1.00	3.758	.038	1.740	1.981	.041	2.306
13	1.00	3.819	.038	1.768	2.013	.041	2.343
14	1.00	3.881	.039	1.797	2.045	.042	2.381
15	1.00	3.945	.039	1.826	2.079	.043	2.420
16	1.00	4.009	.040	1.856	2.113	.043	2.460
17	1.00	4.075	.041	1.887	2.148	.044	2.500
18	1.00	4.142	.041	1.918	2.183	.045	2.542
19	1.00	4.211	.042	1.950	2.219	.045	2.584
20	1.00	4.281	.043	1.982	2.256	.046	2.627
TOTALS		73.770	.738	34.155	38.877	.797	45.260

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 5 -- Increase offset from 2 to 7 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.889
TOTAL ROADSIDE ACCIDENTS REDUCED:	75.07
NET PDO ACCIDENTS REDUCED:	37.79
NET FATALITIES PREVENTED:	.85
NET INJURIES PREVENTED:	47.32
TOTAL ACCIDENT SAVINGS:	902363.50

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	91907.70
BENEFIT-COST RATIO:	19.281

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 6 -- Increase offset from 2 to 8 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	8 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	2.913	.029	1.349	1.535	.031	1.787
2	1.00	2.958	.030	1.369	1.559	.032	1.815
3	1.00	3.004	.030	1.391	1.583	.032	1.843
4	1.00	3.051	.031	1.413	1.608	.033	1.872
5	1.00	3.099	.031	1.435	1.633	.033	1.901
6	1.00	3.148	.031	1.457	1.659	.034	1.931
7	1.00	3.198	.032	1.481	1.685	.035	1.962
8	1.00	3.249	.032	1.504	1.712	.035	1.993
9	1.00	3.301	.033	1.528	1.739	.036	2.025
10	1.00	3.354	.034	1.553	1.767	.036	2.058
11	1.00	3.408	.034	1.578	1.796	.037	2.091
12	1.00	3.463	.035	1.603	1.825	.037	2.125
13	1.00	3.519	.035	1.629	1.855	.038	2.159
14	1.00	3.576	.036	1.656	1.885	.039	2.194
15	1.00	3.635	.036	1.683	1.916	.039	2.230
16	1.00	3.694	.037	1.711	1.947	.040	2.267
17	1.00	3.755	.038	1.739	1.979	.041	2.304
18	1.00	3.817	.038	1.767	2.012	.041	2.342
19	1.00	3.881	.039	1.797	2.045	.042	2.381
20	1.00	3.945	.039	1.827	2.079	.043	2.421
TOTALS		67.967	.680	31.469	35.818	.734	41.700

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 6 -- Increase offset from 2 to 8 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.889
TOTAL ROADSIDE ACCIDENTS REDUCED:	80.23
NET PDO ACCIDENTS REDUCED:	40.38
NET FATALITIES PREVENTED:	.91
NET INJURIES PREVENTED:	50.57
TOTAL ACCIDENT SAVINGS:	964367.60

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	98222.95
BENEFIT-COST RATIO:	20.606

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 7 -- Increase offset from 2 to 9 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER	
POLE DENSITY	36	36	POLES/MILE
POLE OFFSET	2	9	FEET
POLE COVERAGE FACTOR	.37	.37	
ROADSIDE COVERAGE FACTOR	.60	.60	
SIDE SLOPE	FILL 10:1	FILL 10:1	
OBSTRUCTED ZONE	20	20	FEET
OBJECTS LINE	9	9	FEET
HINGE LINE	20	20	FEET
POLE TYPE	2	2	

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	TOTAL	ACCIDENTS FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	2.708	.027	1.254	1.427	.029	1.662
2	1.00	2.751	.028	1.273	1.450	.030	1.688
3	1.00	2.794	.028	1.293	1.472	.030	1.714
4	1.00	2.837	.028	1.314	1.495	.031	1.741
5	1.00	2.882	.029	1.334	1.519	.031	1.768
6	1.00	2.928	.029	1.355	1.543	.032	1.796
7	1.00	2.974	.030	1.377	1.567	.032	1.825
8	1.00	3.022	.030	1.399	1.592	.033	1.854
9	1.00	3.070	.031	1.421	1.618	.033	1.884
10	1.00	3.119	.031	1.444	1.644	.034	1.914
11	1.00	3.170	.032	1.468	1.670	.034	1.945
12	1.00	3.221	.032	1.491	1.697	.035	1.976
13	1.00	3.273	.033	1.516	1.725	.035	2.008
14	1.00	3.327	.033	1.540	1.753	.036	2.041
15	1.00	3.381	.034	1.566	1.782	.037	2.075
16	1.00	3.437	.034	1.591	1.811	.037	2.109
17	1.00	3.494	.035	1.618	1.841	.038	2.143
18	1.00	3.551	.036	1.644	1.872	.038	2.179
19	1.00	3.610	.036	1.672	1.903	.039	2.215
20	1.00	3.671	.037	1.700	1.934	.040	2.252
TOTALS		63.220	.632	29.271	33.317	.683	38.787

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 7 -- Increase offset from 2 to 9 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.889
TOTAL ROADSIDE ACCIDENTS REDUCED:	84.45
NET PDO ACCIDENTS REDUCED:	42.51
NET FATALITIES PREVENTED:	.96
NET INJURIES PREVENTED:	53.23
TOTAL ACCIDENT SAVINGS:	1015084.00

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	103388.50
BENEFIT-COST RATIO:	21.690

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 8 -- Increase offset from 2 to 10 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	10 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	2.538	.025	1.175	1.337	.027	1.557
2	1.00	2.577	.026	1.193	1.358	.028	1.581
3	1.00	2.617	.026	1.212	1.379	.028	1.606
4	1.00	2.659	.027	1.231	1.401	.029	1.631
5	1.00	2.701	.027	1.250	1.423	.029	1.657
6	1.00	2.743	.027	1.270	1.446	.030	1.683
7	1.00	2.787	.028	1.290	1.469	.030	1.710
8	1.00	2.832	.028	1.311	1.492	.031	1.737
9	1.00	2.877	.029	1.332	1.516	.031	1.765
10	1.00	2.923	.029	1.354	1.541	.032	1.794
11	1.00	2.971	.030	1.375	1.566	.032	1.823
12	1.00	3.019	.030	1.398	1.591	.033	1.852
13	1.00	3.068	.031	1.420	1.617	.033	1.882
14	1.00	3.118	.031	1.444	1.643	.034	1.913
15	1.00	3.169	.032	1.467	1.670	.034	1.944
16	1.00	3.221	.032	1.492	1.698	.035	1.976
17	1.00	3.275	.033	1.516	1.726	.035	2.009
18	1.00	3.329	.033	1.541	1.754	.036	2.042
19	1.00	3.384	.034	1.567	1.784	.037	2.076
20	1.00	3.441	.034	1.593	1.813	.037	2.111
TOTALS		59.249	.592	27.432	31.224	.640	36.351

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 8 -- Increase offset from 2 to 10 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.843
TOTAL ROADSIDE ACCIDENTS REDUCED:	83.45
NET PDO ACCIDENTS REDUCED:	41.04
NET FATALITIES PREVENTED:	.97
NET INJURIES PREVENTED:	53.29
TOTAL ACCIDENT SAVINGS:	1020903.00

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	103981.20
BENEFIT-COST RATIO:	21.814

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 9 -- Increase offset from 2 to 11 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	11 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	2.392	.024	1.108	1.261	.026	1.468
2	1.00	2.429	.024	1.125	1.280	.026	1.491
3	1.00	2.468	.025	1.142	1.300	.027	1.514
4	1.00	2.506	.025	1.160	1.321	.027	1.538
5	1.00	2.546	.025	1.179	1.342	.027	1.562
6	1.00	2.586	.026	1.198	1.363	.028	1.587
7	1.00	2.628	.026	1.217	1.385	.028	1.612
8	1.00	2.670	.027	1.236	1.407	.029	1.638
9	1.00	2.713	.027	1.256	1.430	.029	1.664
10	1.00	2.756	.028	1.276	1.453	.030	1.691
11	1.00	2.801	.028	1.297	1.476	.030	1.719
12	1.00	2.847	.028	1.318	1.500	.031	1.746
13	1.00	2.893	.029	1.339	1.525	.031	1.775
14	1.00	2.940	.029	1.361	1.550	.032	1.804
15	1.00	2.989	.030	1.384	1.575	.032	1.834
16	1.00	3.038	.030	1.407	1.601	.033	1.864
17	1.00	3.088	.031	1.430	1.628	.033	1.895
18	1.00	3.140	.031	1.454	1.655	.034	1.926
19	1.00	3.192	.032	1.478	1.682	.034	1.958
20	1.00	3.245	.032	1.503	1.710	.035	1.991
TOTALS		55.867	.559	25.866	29.442	.603	34.276

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 9 -- Increase offset from 2 to 11 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.805
TOTAL ROADSIDE ACCIDENTS REDUCED:	82.36
NET PDO ACCIDENTS REDUCED:	39.62
NET FATALITIES PREVENTED:	.98
NET INJURIES PREVENTED:	53.23
TOTAL ACCIDENT SAVINGS:	1023908.00

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	104287.30
BENEFIT-COST RATIO:	21.878

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 10 -- Increase offset from 2 to 12 ft.

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	12 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	2.266	.023	1.049	1.194	.024	1.390
2	1.00	2.302	.023	1.066	1.213	.025	1.412
3	1.00	2.338	.023	1.082	1.232	.025	1.434
4	1.00	2.375	.024	1.100	1.252	.026	1.457
5	1.00	2.412	.024	1.117	1.271	.026	1.480
6	1.00	2.451	.025	1.135	1.292	.026	1.504
7	1.00	2.490	.025	1.153	1.312	.027	1.528
8	1.00	2.530	.025	1.171	1.333	.027	1.552
9	1.00	2.571	.026	1.190	1.355	.028	1.577
10	1.00	2.612	.026	1.209	1.377	.028	1.603
11	1.00	2.655	.027	1.229	1.399	.029	1.629
12	1.00	2.698	.027	1.249	1.422	.029	1.655
13	1.00	2.742	.027	1.269	1.445	.030	1.682
14	1.00	2.787	.028	1.290	1.469	.030	1.710
15	1.00	2.833	.028	1.311	1.493	.031	1.738
16	1.00	2.879	.029	1.333	1.517	.031	1.767
17	1.00	2.927	.029	1.355	1.543	.032	1.796
18	1.00	2.976	.030	1.378	1.568	.032	1.826
19	1.00	3.025	.030	1.401	1.594	.033	1.856
20	1.00	3.076	.031	1.424	1.621	.033	1.887
TOTALS		52.944	.529	24.513	27.901	.572	32.483

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

ALTERNATIVE 10 -- Increase offset from 2 to 12 ft.

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	1.00
INJURY ACC. REDUCTION FACTOR:	1.00
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	.762
TOTAL ROADSIDE ACCIDENTS REDUCED:	80.21
NET PDO ACCIDENTS REDUCED:	37.53
NET FATALITIES PREVENTED:	.97
NET INJURIES PREVENTED:	52.59
TOTAL ACCIDENT SAVINGS:	1016715.00

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	total costs	INITIAL COST	0	20	46800.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	4766.68
EQUIVALENT UNIFORM ANNUAL BENEFIT:	103554.60
BENEFIT-COST RATIO:	21.725

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 21 89

COMPARATIVE ECONOMIC ANALYSIS RESULTS

SUMMARY OF ALTERNATIVES

#	DESCRIPTION
0	DO NOTHING
1	Increase offset from 2 to 3 ft.
2	Increase offset from 2 to 4 ft.
3	Increase offset from 2 to 5 ft.
4	Increase offset from 2 to 6 ft.
5	Increase offset from 2 to 7 ft.
6	Increase offset from 2 to 8 ft.
7	Increase offset from 2 to 9 ft.
8	Increase offset from 2 to 10 ft.
9	Increase offset from 2 to 11 ft.
10	Increase offset from 2 to 12 ft.

INCREMENTAL BENEFIT-COST ANALYSIS RESULTS

ALTERNATIVE	CAPITAL COST	EUAC	EUAB	B/C RATIO	COMPARED ALTS	INCREMENTAL B/C RATIO
0	0.	0.	0.	1.000		
					1 - 0	7.880
1	46800.	4767.	37560.	7.880		
					2 - 1	21619.300
2	46800.	4767.	59179.	12.415		
					3 - 2	14379.540
3	46800.	4767.	73559.	15.432		
					4 - 3	10400.760
4	46800.	4767.	83960.	17.614		
					5 - 4	7948.188
5	46800.	4767.	91908.	19.281		
					6 - 5	6315.250
6	46800.	4767.	98223.	20.606		
					7 - 6	5165.531
7	46800.	4767.	103388.	21.690		
					8 - 7	592.750
8	46800.	4767.	103981.	21.814		
					9 - 8	306.063
9	46800.	4767.	104287.	21.878		
					10 - 9	-732.656

10	46800.	4767.	103555.	21.725

***** NORMAL PROGRAM END *****

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

SECTION CHARACTERISTICS

Breakaway Street Lighting (CF = 0.60)

72 poles x $300/pole = $21,600
72 poles x $750/pole = $54,000

Use both 50% and 70% reduction in severity for injury plus fatal accidents

SEGMENT

BEG. MILEPOST:	.00	END MILEPOST:	2.00
LENGTH (MILES):	2.00		

ROADWAY

ROAD ALIGNMENT:	TANGENT	SHOULDER TYPE:	CURBED
NUMBER OF LANES:	4	RIGHT-OF-WAY WIDTH:	60 FT
ROAD WIDTH:	48.0 FT	TRAFFIC FLOW:	TWO-WAY
TERRRAIN:	FLAT	AREA TYPE:	URBAN
PAVEMENT:	CONCRETE	ROADSIDE COVERAGE:	.60
SIDE SLOPE:	FILL 10:1	OBJECTS LINE:	9 FT
HINGE LINE:	20 FT	OBSTRUCTED ZONE:	20 FT

UTILITY POLES

POLE CONFIGURATION:	ONE SIDE	POLE TYPE:	METAL
NUMBER OF POLES:	72	POLE USE:	
POLE OFFSET:	2 FT	LINE TYPE:	69KV 1 PHASE

TRAFFIC

SPEED LIMIT:	40. MPH	GROWTH FACTOR CODE:	1
BASE YEAR ADT:	500. VEH	GROWTH RATE(%):	2.00

UTILITY POLE ACCIDENTS PER YEAR

TOTAL ACCIDENTS:	1.67	FATAL ACCIDENTS:	.02(1.0%)
INJURY ACCIDENTS:	.77(46.3%)	PROPERTY DAMAGE:	.88(52.7%)
FATALITIES:	.02	FATALITIES/FATAL ACC:	1.08
INJURIES:	1.02	INJURIES/FATAL ACC:	.70
INJURIES/INJURY ACC:	1.31		

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

DATA PROJECTIONS SUMMARY FOR SECTION

YEAR	ADT	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	500.	1.00	1.667	.017	.772	.878	.018	1.022
2	510.	1.00	1.668	.017	.772	.879	.018	1.023
3	520.	1.00	1.669	.017	.773	.880	.018	1.024
4	531.	1.00	1.670	.017	.773	.880	.018	1.025
5	541.	1.00	1.672	.017	.774	.881	.018	1.026
6	552.	1.00	1.673	.017	.775	.882	.018	1.027
7	563.	1.00	1.675	.017	.775	.883	.018	1.027
8	574.	1.00	1.676	.017	.776	.883	.018	1.028
9	586.	1.00	1.678	.017	.777	.884	.018	1.029
10	598.	1.00	1.679	.017	.777	.885	.018	1.030
11	609.	1.00	1.681	.017	.778	.886	.018	1.031
12	622.	1.00	1.682	.017	.779	.887	.018	1.032
13	634.	1.00	1.684	.017	.780	.887	.018	1.033
14	647.	1.00	1.686	.017	.780	.888	.018	1.034
15	660.	1.00	1.687	.017	.781	.889	.018	1.035
16	673.	1.00	1.689	.017	.782	.890	.018	1.036
17	686.	1.00	1.691	.017	.783	.891	.018	1.037
18	700.	1.00	1.692	.017	.784	.892	.018	1.038
19	714.	1.00	1.694	.017	.784	.893	.018	1.040
20	728.	1.00	1.696	.017	.785	.894	.018	1.041
TOTALS			33.609	.336	15.561	17.712	.363	20.620

$$(100)\frac{0.336 + 15.561}{33.609} = 47.3\%$$

$$(100)\frac{0.336}{33.609} = 1\%$$

$$(100)\frac{15.561}{33.609} = 46.3\%$$

WARNING: ROADSIDE ADJUSTMENT FACTOR SET TO 1.00

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

ALTERNATIVE 1 -- Breakaway Poles (50% reduction in severity)

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	2 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	1.667	.008	.386	1.272	.009	.511
2	1.00	1.668	.008	.386	1.273	.009	.512
3	1.00	1.669	.008	.386	1.274	.009	.512
4	1.00	1.670	.008	.387	1.275	.009	.512
5	1.00	1.672	.008	.387	1.276	.009	.513
6	1.00	1.673	.008	.387	1.278	.009	.513
7	1.00	1.675	.008	.388	1.279	.009	.514
8	1.00	1.676	.008	.388	1.280	.009	.514
9	1.00	1.678	.008	.388	1.281	.009	.515
10	1.00	1.679	.008	.389	1.282	.009	.515
11	1.00	1.681	.008	.389	1.283	.009	.516
12	1.00	1.682	.008	.389	1.284	.009	.516
13	1.00	1.684	.008	.390	1.286	.009	.517
14	1.00	1.686	.008	.390	1.287	.009	.517
15	1.00	1.687	.008	.391	1.288	.009	.518
16	1.00	1.689	.008	.391	1.290	.009	.518
17	1.00	1.691	.008	.391	1.291	.009	.519
18	1.00	1.692	.008	.392	1.292	.009	.519
19	1.00	1.694	.008	.392	1.294	.009	.520
20	1.00	1.696	.008	.393	1.295	.009	.520
TOTALS		33.609	.168	7.780	25.660	.181	10.310

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

$$(100)\frac{0.168 + 7.780}{33.609} = 23.65\%$$ (50% reduction)

$$(100)\frac{0.168}{33.609} = 0.5\%$$ (50% reduction)

$$(100)\frac{7.780}{33.609} = 23.15\%$$ (50% reduction)

$$(100)\frac{25.660}{17.712} = 145\%$$ increase in PDO's

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

ALTERNATIVE 1 -- Breakaway Poles (50% reduction in severity)

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	.50
INJURY ACC. REDUCTION FACTOR:	.50
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	1.000
TOTAL ROADSIDE ACCIDENTS REDUCED:	.00
NET PDO ACCIDENTS REDUCED:	-7.95
NET FATALITIES PREVENTED:	.18
NET INJURIES PREVENTED:	10.31
TOTAL ACCIDENT SAVINGS:	177207.70

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	breakaway costs	INITIAL COST	0	20	21600.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	2200.01
EQUIVALENT UNIFORM ANNUAL BENEFIT:	18048.99
BENEFIT-COST RATIO:	8.204

WARNING: ROADSIDE ADJUSTMENT FACTOR SET TO 1.00

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

ALTERNATIVE 2 -- Breakaway Poles (75% reduction in severity)

SUMMARY OF CHANGES

	BEFORE	AFTER
POLE DENSITY	36	36 POLES/MILE
POLE OFFSET	2	2 FEET
POLE COVERAGE FACTOR	.37	.37
ROADSIDE COVERAGE FACTOR	.60	.60
SIDE SLOPE	FILL 10:1	FILL 10:1
OBSTRUCTED ZONE	20	20 FEET
OBJECTS LINE	9	9 FEET
HINGE LINE	20	20 FEET
POLE TYPE	2	2

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

EXPECTED UTILITY POLE ACCIDENTS AFTER IMPROVEMENT

YEAR	SEVERITY FACTOR	ACCIDENTS TOTAL	FATAL	INJURY	PDO	PERSONS KILLED	INJURED
1	1.00	1.667	.005	.231	1.430	.005	.307
2	1.00	1.668	.005	.232	1.431	.005	.307
3	1.00	1.669	.005	.232	1.432	.005	.307
4	1.00	1.670	.005	.232	1.433	.005	.307
5	1.00	1.672	.005	.232	1.435	.005	.308
6	1.00	1.673	.005	.232	1.436	.005	.308
7	1.00	1.675	.005	.233	1.437	.005	.308
8	1.00	1.676	.005	.233	1.438	.005	.309
9	1.00	1.678	.005	.233	1.440	.005	.309
10	1.00	1.679	.005	.233	1.441	.005	.309
11	1.00	1.681	.005	.233	1.442	.005	.309
12	1.00	1.682	.005	.234	1.444	.005	.310
13	1.00	1.684	.005	.234	1.445	.005	.310
14	1.00	1.686	.005	.234	1.446	.005	.310
15	1.00	1.687	.005	.234	1.448	.005	.311
16	1.00	1.689	.005	.235	1.449	.005	.311
17	1.00	1.691	.005	.235	1.451	.005	.311
18	1.00	1.692	.005	.235	1.452	.005	.312
19	1.00	1.694	.005	.235	1.454	.005	.312
20	1.00	1.696	.005	.236	1.455	.005	.312
TOTALS		33.609	.101	4.668	28.840	.109	6.186

NOTE:
1. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR ROADSIDE FEATURES.
2. ACCIDENT/SEVERITY PROJECTIONS NOT ADJUSTED FOR URBAN AREA EFFECTS.

$$(100)\frac{0.101 + 4.668}{33.609} = 14.19\% \quad (70\% \text{ reduction})$$

$$(100)\frac{0.101}{33.609} = 0.3\% \quad (70\% \text{ reduction})$$

$$(100)\frac{4.668}{33.609} = 13.89\% \quad (70\% \text{ reduction})$$

$$(100)\frac{28.840}{17.712} = 163\% \text{ increase in PDO's}$$

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

ALTERNATIVE 2 -- Breakaway Poles (75% reduction in severity)

ANALYSIS PARAMETERS

PROJECT LIFE:	20 YEARS
INTEREST RATE:	8.00 %
COST/FATALITY:	$1500000.
COST/INJURY:	$ 11000.
COST/PDO ACC:	$ 3000.
FATAL ACC. REDUCTION FACTOR:	.30
INJURY ACC. REDUCTION FACTOR:	.30
PDO ACC. REDUCTION FACTOR:	1.00

ACCIDENT REDUCTION DATA

ROADSIDE ADJUSTMENT FACTOR:	1.000
TOTAL ROADSIDE ACCIDENTS REDUCED:	.00
NET PDO ACCIDENTS REDUCED:	-11.13
NET FATALITIES PREVENTED:	.25
NET INJURIES PREVENTED:	14.43
TOTAL ACCIDENT SAVINGS:	248090.80

COUNTERMEASURE DATA

ITEM	DESCRIPTION	TYPE	START YEAR	END YEAR	AMOUNT
1	breakaway costs	INITIAL COST	0	20	21600.00

ECONOMIC ANALYSIS RESULTS

EQUIVALENT UNIFORM ANNUAL COST:	2200.01
EQUIVALENT UNIFORM ANNUAL BENEFIT:	25268.59
BENEFIT-COST RATIO:	11.486

SECTION: General Example
LOCATION: U.S.A.
SECTION ID: 0004

RUN BY: Ronald K. Faller
AGENCY: University of Nebraska
DATE: 11 24 89

COMPARATIVE ECONOMIC ANALYSIS RESULTS

SUMMARY OF ALTERNATIVES

#	DESCRIPTION
0	DO NOTHING
1	Breakaway Poles (50% reduction in severity)
2	Breakaway Poles (75% reduction in severity)

INCREMENTAL BENEFIT-COST ANALYSIS RESULTS

ALTERNATIVE	CAPITAL COST	EUAC	EUAB	B/C RATIO	COMPARED ALTS	INCREMENTAL B/C RATIO
0	0.	0.	0.	1.000		
					1 - 0	8.204
1	21600.	2200.	18049.	8.204		
					2 - 1	7219.598
2	21600.	2200.	25269.	11.486		

***** NORMAL PROGRAM END *****

APPENDIX M

"ROADSIDE" COMPUTER RUN (RELOCATION EXAMPLE)

LIGHT POLES 5-2, 5-10

2 LANE ROADWAY

GLOBAL PARAMETERS

```
 1. FATALITY COST             = $ 1,500,000
 2. SEVERE INJURY COST        = $   110,000
 3. MODERATE INJURY COST      = $    11,000
 4. SLIGHT INJURY COST        = $     3,000
 5. PDO LEVEL 2 COST          = $     3,000
 6. PDO LEVEL 1 COST          = $       500
 7. ENCROACHMENT RATE MODEL = 0.001330 * (ADTeff ^ 1.000000 )
                                ENCROACHMENTS PER MILE PER YEAR
 8. ENCROACHMENT ANGLE AT 40 MPH =   17.2 DEGREES
 9. ENCROACHMENT ANGLE AT 50 MPH =   15.2 DEGREES
10. ENCROACHMENT ANGLE AT 60 MPH =   13.0 DEGREES
11. ENCROACHMENT ANGLE AT 70 MPH =   11.6 DEGREES
12. LIMTING TRAFFIC VOLUME PER LANE =   10,000 VEHICLES PER DAY
13. SWATH WIDTH =        12 FT.
```

SEVERITY INDEX	COST
0.0	$ 0
0.5	$ 500
1.0	$ 1,517
2.0	$ 3,560
3.0	$ 20,720
4.0	$ 55,820
5.0	$137,060
6.0	$296,980
7.0	$486,440
8.0	$781,910
9.0	$%1,145,570
10.0	$%1,500,000

```
 1. TITLE:    LIGHT POLE 5-2

 2. INITIAL TRAFFIC VOLUME =    5,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR    DESIGN YEAR ADT =    7,430
    LIMITING TRAFFIC VOLUME PER LANE  =   10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 FT.

 4. CURVATURE =   0.0 DEGREES            GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
              TRAFFIC   BASELINE   CURVATURE   GRADE    USER    TOTAL
              VOLUME      ENC.       FACTOR    FACTOR   FACTOR   ENC.
    ADJACENT   2,500     3.3250      1.00       1.00     1.0    3.3250
    OPPOSING   2,500     3.3250      1.00       1.00     1.0    3.3250

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)     =          2. FT.
    LONGITUDINAL LENGTH (L) =          1. FT.
    WIDTH OF OBSTACLE         =          1. FT.
                    ZONE1        ZONE2        ZONE3
    ADJACENT       0.0020       0.0256       0.0006   ENCROACHMENTS/YEAR
    OPPOSING       0.0020       0.0256       0.0006   ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =       0.015 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =       0.363
    ADJACENT     CFT=  0.0114  CF1 =  0.0004  CF2 =  0.0105  CF3 = 0.0004
    OPPOSING     CFT=  0.0034  CF4 =  0.0001  CF5 =  0.0032  CF6 =  0.0001

 9. SEVERITY INDEX =    3.80          3.80         3.80        3.80          3.80
                     SIDEUP        SIDEDOWN     UP CORNER   DOWN CORNER      FACE
    ACCIDENT COST = $   48,800  $   48,800  $   48,800  $   48,800  $   48,800
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE       OF HAZARD = $        20
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE     OF HAZARD = $         7
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER     OF HAZARD = $       512
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER   OF HAZARD = $       155
    INITIAL COST/YEAR IMPACTS WITH  FACE                OF HAZARD = $        27
                                    TOTAL INITIAL ACCIDENT COST = $       722.

10. PROJECT LIFE =  20 YEARS         DISCOUNT RATE =  8.0 %
    KT =     9.818    KJ =      0.215    CRF =    0.102     KC  =  11.466

11. COST OF INSTALLATION              = $          0.
12. COST OF REPAIR  $ SU=       650  SD=      650  CU=      650  CD=      650  F=      650

13. MAINTENANCE COST PER YEAR         = $         10.
14. SALVAGE VALUE                     = $          0.

15. TOTAL PRESENT WORTH               = $      8,482.    ANNUALIZED $        864.
    HIGHWAY DEPARTMENT COST           = $        208.    ANNUALIZED $         21.

    INSTALLATION COST =                 $          0.    ANNUALIZED $          0.
    REPAIR COST       =                 $        110.    ANNUALIZED $         11.
    MAINTENANCE COST  =                 $         98.    ANNUALIZED $         10.
    SALVAGE VALUE     =                 $          0.    ANNUALIZED $          0.
    ACCIDENT COST     =                 $      8,274.    ANNUALIZED $        843.
```

1. TITLE: LIGHT POLE 5-3

2. INITIAL TRAFFIC VOLUME = 5,000 VEHICLES PER DAY
TRAFFIC GROWTH RATE = 2.0 % PER YEAR DESIGN YEAR ADT = 7,430
LIMITING TRAFFIC VOLUME PER LANE = 10,000

3. UNDIVIDED HIGHWAY LANE(S) OF ADJACENT TRAFFIC = 1. LANE WIDTH = 12.0 F

4. CURVATURE = 0.0 DEGREES GRADE (PERCENTAGE) = 0.0

5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)

	TRAFFIC VOLUME	BASELINE ENC.	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC.
ADJACENT	2,500	3.3250	1.00	1.00	1.0	3.3250
OPPOSING	2,500	3.3250	1.00	1.00	1.0	3.3250

6. DESIGN SPEED = 40 MPH ENCROACHMENT ANGLE = 17.2 SWATH WIDTH = 12.0

7. LATERAL PLACEMENT (A) = 3. FT.
LONGITUDINAL LENGTH (L) = 1. FT.
WIDTH OF OBSTACLE = 1. FT.

	ZONE1	ZONE2	ZONE3	
ADJACENT	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR
OPPOSING	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR

8. INITIAL COLLISION FREQUENCY = 0.013 IMPACTS PER YEAR
EXPECTED IMPACTS OVER PROJECT LIFE = 0.326
ADJACENT CFT= 0.0102 CF1 = 0.0004 CF2 = 0.0094 CF3 = 0.0004
OPPOSING CFT= 0.0031 CF4 = 0.0001 CF5 = 0.0029 CF6 = 0.0001

9.

	SIDEUP	SIDEDOWN	UP CORNER	DOWN CORNER	FACE
SEVERITY INDEX =	3.80	3.80	3.80	3.80	3.80
ACCIDENT COST =	$ 48,800	$ 48,800	$ 48,800	$ 48,800	$ 48,800

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF HAZARD = $ 19
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF HAZARD = $ 6
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF HAZARD = $ 459
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF HAZARD = $ 141
INITIAL COST/YEAR IMPACTS WITH FACE OF HAZARD = $ 24
TOTAL INITIAL ACCIDENT COST = $ 649.

10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 8.0 %
KT = 9.818 KJ = 0.215 CRF = 0.102 KC = 11.466

11. COST OF INSTALLATION = $ 650.
12. COST OF REPAIR $ SU= 650 SD= 650 CU= 650 CD= 650 F= 65

13. MAINTENANCE COST PER YEAR = $ 10.
14. SALVAGE VALUE = $ 0.

15. TOTAL PRESENT WORTH = $ 8,288. ANNUALIZED $ 844.
HIGHWAY DEPARTMENT COST = $ 847. ANNUALIZED $ 86.

INSTALLATION COST =	$ 650.	ANNUALIZED $ 66.
REPAIR COST =	$ 99.	ANNUALIZED $ 10.
MAINTENANCE COST =	$ 98.	ANNUALIZED $ 10.
SALVAGE VALUE =	$ 0.	ANNUALIZED $ 0.
ACCIDENT COST =	$ 7,441.	ANNUALIZED $ 758.

1. TITLE: LIGHT POLE 5-5

2. INITIAL TRAFFIC VOLUME = 5,000 VEHICLES PER DAY
   TRAFFIC GROWTH RATE = 2.0 % PER YEAR DESIGN YEAR ADT = 7,430
   LIMITING TRAFFIC VOLUME PER LANE = 10,000

3. UNDIVIDED HIGHWAY LANE(S) OF ADJACENT TRAFFIC = 1. LANE WIDTH = 12.0 FT.

4. CURVATURE = 0.0 DEGREES GRADE (PERCENTAGE) = 0.0

5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)

	TRAFFIC VOLUME	BASELINE ENC.	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC.
ADJACENT	2,500	3.3250	1.00	1.00	1.0	3.3250
OPPOSING	2,500	3.3250	1.00	1.00	1.0	3.3250

6. DESIGN SPEED = 40 MPH ENCROACHMENT ANGLE = 17.2 SWATH WIDTH = 12.0

7. LATERAL PLACEMENT (A) = 5. FT.
   LONGITUDINAL LENGTH (L) = 1. FT.
   WIDTH OF OBSTACLE = 1. FT.

	ZONE1	ZONE2	ZONE3	
ADJACENT	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR
OPPOSING	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR

8. INITIAL COLLISION FREQUENCY = 0.011 IMPACTS PER YEAR
   EXPECTED IMPACTS OVER PROJECT LIFE = 0.266
   ADJACENT CFT= 0.0082 CF1 = 0.0003 CF2 = 0.0076 CF3 = 0.0003
   OPPOSING CFT= 0.0026 CF4 = 0.0001 CF5 = 0.0024 CF6 = 0.0001

9. SEVERITY INDEX =

	SIDEUP	SIDEDOWN	UP CORNER	DOWN CORNER	FACE
SEVERITY INDEX	3.80	3.80	3.80	3.80	3.80
ACCIDENT COST	$ 48,800	$ 48,800	$ 48,800	$ 48,800	$ 48,80

   INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF HAZARD = $ 15
   INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF HAZARD = $ 5
   INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF HAZARD = $ 372
   INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF HAZARD = $ 117
   INITIAL COST/YEAR IMPACTS WITH FACE OF HAZARD = $ 19
   TOTAL INITIAL ACCIDENT COST = $ 528.

10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 8.0 %
    KT = 9.818 KJ = 0.215 CRF = 0.102 KC = 11.466

11. COST OF INSTALLATION = $ 650.
12. COST OF REPAIR $ SU= 650 SD= 650 CU= 650 CD= 650 F= 650

13. MAINTENANCE COST PER YEAR = $ 10.
14. SALVAGE VALUE = $ 0.

15. TOTAL PRESENT WORTH = $ 6,886. ANNUALIZED $ 701.
    HIGHWAY DEPARTMENT COST = $ 829. ANNUALIZED $ 84.

INSTALLATION COST =	$ 650.	ANNUALIZED $	66.
REPAIR COST =	$ 81.	ANNUALIZED $	8.
MAINTENANCE COST =	$ 98.	ANNUALIZED $	10.
SALVAGE VALUE =	$ 0.	ANNUALIZED $	0.
ACCIDENT COST =	$ 6,057.	ANNUALIZED $	617.

```
 1. TITLE:    LIGHT POLE 5-4

 2. INITIAL TRAFFIC VOLUME =   5,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR    DESIGN YEAR ADT =    7,430
    LIMITING TRAFFIC VOLUME PER LANE  =  10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 FT.

 4. CURVATURE =   0.0 DEGREES           GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
             TRAFFIC   BASELINE   CURVATURE   GRADE     USER    TOTAL
             VOLUME      ENC.       FACTOR    FACTOR   FACTOR   ENC.
    ADJACENT  2,500     3.3250      1.00      1.00      1.0    3.3250
    OPPOSING  2,500     3.3250      1.00      1.00      1.0    3.3250

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)     =        4. FT.
    LONGITUDINAL LENGTH (L) =        1. FT.
    WIDTH OF OBSTACLE         =        1. FT.
                          ZONE1        ZONE2        ZONE3
    ADJACENT             0.0020       0.0256       0.0006   ENCROACHMENTS/YEAR
    OPPOSING             0.0020       0.0256       0.0006   ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =       0.012 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =      0.294
    ADJACENT     CFT=  0.0091  CF1 =  0.0003  CF2 =  0.0084  CF3 =  0.0003
    OPPOSING     CFT=  0.0028  CF4 =  0.0001  CF5 =  0.0026  CF6 =  0.0001

 9. SEVERITY INDEX =    3.80          3.80         3.80         3.80         3.80
                      SIDEUP      SIDEDOWN   UP CORNER  DOWN CORNER       FACE
    ACCIDENT COST = $   48,800  $   48,800  $   48,800  $   48,800  $   48,800
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE         OF HAZARD = $       17
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE       OF HAZARD = $        5
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER       OF HAZARD = $      412
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER     OF HAZARD = $      128
    INITIAL COST/YEAR IMPACTS WITH  FACE                  OF HAZARD = $       22
                                      TOTAL INITIAL ACCIDENT COST = $      584.

10. PROJECT LIFE =  20 YEARS        DISCOUNT RATE =  8.0 %
    KT =     9.818    KJ =     0.215    CRF =    0.102    KC   = 11.466

11. COST OF INSTALLATION             = $        650.
12. COST OF REPAIR  $ SU=      650  SD=      650  CU=      650  CD=     650  F=     650

13. MAINTENANCE COST PER YEAR        = $         10.
14. SALVAGE VALUE                    = $          0.

15. TOTAL PRESENT WORTH              = $      7,535.     ANNUALIZED $        767.
    HIGHWAY DEPARTMENT COST          = $        837.     ANNUALIZED $         85.

    INSTALLATION COST =                $        650.     ANNUALIZED $         66.
    REPAIR COST       =                $         89.     ANNUALIZED $          9.
    MAINTENANCE COST  =                $         98.     ANNUALIZED $         10.
    SALVAGE VALUE     =                $          0.     ANNUALIZED $          0.
    ACCIDENT COST     =                $      6,698.     ANNUALIZED $        682.
```

```
  1. TITLE:    LIGHT POLE 5-6

  2. INITIAL TRAFFIC VOLUME =   5,000 VEHICLES PER DAY
     TRAFFIC GROWTH RATE =  2.0 % PER YEAR   DESIGN YEAR ADT =    7,430
     LIMITING TRAFFIC VOLUME PER LANE  =   10,000

  3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 FT.

  4. CURVATURE =   0.0 DEGREES        GRADE (PERCENTAGE) =   0.0

  5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
               TRAFFIC   BASELINE  CURVATURE   GRADE    USER   TOTAL
               VOLUME     ENC.       FACTOR    FACTOR  FACTOR   ENC.
     ADJACENT  2,500     3.3250     1.00      1.00     1.0    3.3250
     OPPOSING  2,500     3.3250     1.00      1.00     1.0    3.3250

  6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

  7. LATERAL PLACEMENT (A)    =        6. FT.
     LONGITUDINAL LENGTH (L) =        1. FT.
     WIDTH OF OBSTACLE        =        1. FT.
                        ZONE1        ZONE2        ZONE3
     ADJACENT          0.0020       0.0256       0.0006   ENCROACHMENTS/YEAR
     OPPOSING          0.0020       0.0256       0.0006   ENCROACHMENTS/YEAR

  8. INITIAL COLLISION FREQUENCY =        0.010 IMPACTS PER YEAR
     EXPECTED IMPACTS OVER PROJECT LIFE =       0.240
     ADJACENT    CFT=  0.0074  CF1 =  0.0003  CF2 =  0.0069  CF3 =  0.0003
     OPPOSING    CFT=  0.0023  CF4 =  0.0001  CF5 =  0.0022  CF6 =  0.0001

  9. SEVERITY INDEX =    3.80          3.80         3.80         3.80        3.80
                        SIDEUP      SIDEDOWN    UP CORNER  DOWN CORNER      FACE
     ACCIDENT COST = $   48,800  $   48,800  $   48,800  $   48,800   $   48,800
     INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE       OF HAZARD = $        14
     INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE     OF HAZARD = $         4
     INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER     OF HAZARD = $       336
     INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER   OF HAZARD = $       106
     INITIAL COST/YEAR IMPACTS WITH  FACE                OF HAZARD = $        17
                                    TOTAL INITIAL ACCIDENT COST = $       478.

 10. PROJECT LIFE =  20 YEARS       DISCOUNT RATE =  8.0 %
     KT =    9.818   KJ =  0.215    CRF =   0.102    KC   =  11.466

 11. COST OF INSTALLATION           = $     650.
 12. COST OF REPAIR  $ SU=      650  SD=    650  CU=      650  CD=      650  F=      650

 13. MAINTENANCE COST PER YEAR      = $      10.
 14. SALVAGE VALUE                  = $       0.

 15. TOTAL PRESENT WORTH            = $   6,298.    ANNUALIZED $       641.
     HIGHWAY DEPARTMENT COST        = $     821.    ANNUALIZED $        84.

     INSTALLATION COST =              $     650.    ANNUALIZED $        66.
     REPAIR COST       =              $      73.    ANNUALIZED $         7.
     MAINTENANCE COST  =              $      98.    ANNUALIZED $        10.
     SALVAGE VALUE     =              $       0.    ANNUALIZED $         0.
     ACCIDENT COST     =              $   5,477.    ANNUALIZED $       558.
```

```
 1. TITLE:    LIGHT POLE 5-7

 2. INITIAL TRAFFIC VOLUME =   5,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR   DESIGN YEAR ADT =    7,430
    LIMITING TRAFFIC VOLUME PER LANE  =  10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 F .

 4. CURVATURE =   0.0 DEGREES           GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
              TRAFFIC   BASELINE   CURVATURE  GRADE      USER    TOTAL
              VOLUME     ENC.        FACTOR    FACTOR    FACTOR   ENC.
    ADJACENT   2,500     3.3250      1.00     1.00       1.0     3.3250
    OPPOSING   2,500     3.3250      1.00     1.00       1.0     3.3250

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)     =        7. FT.
    LONGITUDINAL LENGTH (L) =        1. FT.
    WIDTH OF OBSTACLE         =        1. FT.
                    ZONE1        ZONE2        ZONE3
    ADJACENT       0.0020       0.0256       0.0006    ENCROACHMENTS/YEAR
    OPPOSING       0.0020       0.0256       0.0006    ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =       0.009 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =      0.218
    ADJACENT     CFT=  0.0067  CF1 =  0.0003  CF2 =  0.0062  CF3 =  0.0002
    OPPOSING     CFT=  0.0021  CF4 =  0.0001  CF5 =  0.0020  CF6 =  0.0001

 9. SEVERITY INDEX =    3.80          3.80         3.80         3.80          3.80
                      SIDEUP       SIDEDOWN    UP CORNER  DOWN CORNER       FACE
    ACCIDENT COST = $    48,800  $   48,800  $   48,800  $   48,800   $   48,80^
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE       OF HAZARD = $         13
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE     OF HAZARD = $          4
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER     OF HAZARD = $        304
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER   OF HAZARD = $         96
    INITIAL COST/YEAR IMPACTS WITH  FACE                OF HAZARD = $         16
                                       TOTAL INITIAL ACCIDENT COST = $        433.

10. PROJECT LIFE =  20 YEARS        DISCOUNT RATE =  8.0 %
    KT =     9.818    KJ =     0.215    CRF =     0.102    KC   =  11.466

11. COST OF INSTALLATION              = $      650.
12. COST OF REPAIR  $ SU=      650  SD=    650  CU=      650  CD=      650  F=      650

13. MAINTENANCE COST PER YEAR         = $        10.
14. SALVAGE VALUE                     = $         0.

15. TOTAL PRESENT WORTH               = $     5,779.     ANNUALIZED $        589.
    HIGHWAY DEPARTMENT COST           = $       814.     ANNUALIZED $         83.

    INSTALLATION COST =                 $       650.     ANNUALIZED $         66.
    REPAIR COST       =                 $        66.     ANNUALIZED $          7.
    MAINTENANCE COST  =                 $        98.     ANNUALIZED $         10.
    SALVAGE VALUE     =                 $         0.     ANNUALIZED $          0.
    ACCIDENT COST     =                 $     4,964.     ANNUALIZED $        506.
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```
 1. TITLE:    LIGHT POLE 5-8

 2. INITIAL TRAFFIC VOLUME =   5,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR    DESIGN YEAR ADT =    7,430
    LIMITING TRAFFIC VOLUME PER LANE   =   10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 FT.

 4. CURVATURE =   0.0 DEGREES            GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
              TRAFFIC   BASELINE   CURVATURE   GRADE    USER    TOTAL
              VOLUME      ENC.      FACTOR    FACTOR   FACTOR   ENC.
    ADJACENT   2,500     3.3250     1.00      1.00      1.0    3.3250
    OPPOSING   2,500     3.3250     1.00      1.00      1.0    3.3250

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)     =          8. FT.
    LONGITUDINAL LENGTH (L) =            1. FT.
    WIDTH OF OBSTACLE         =          1. FT.
                     ZONE1        ZONE2         ZONE3
    ADJACENT        0.0020       0.0256        0.0006   ENCROACHMENTS/YEAR
    OPPOSING        0.0020       0.0256        0.0006   ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =      0.008 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =      0.197
    ADJACENT    CFT=  0.0061  CF1 =  0.0002  CF2 =  0.0056  CF3 =  0.0002
    OPPOSING    CFT=  0.0019  CF4 =  0.0001  CF5 =  0.0018  CF6 =  0.0001

 9. SEVERITY INDEX =    3.80          3.80          3.80          3.80          3.80
                       SIDEUP      SIDEDOWN    UP CORNER   DOWN CORNER       FACE
    ACCIDENT COST = $   48,800  $   48,800  $   48,800  $   48,800   $   48,800
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE       OF HAZARD = $        12
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE     OF HAZARD = $         4
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER     OF HAZARD = $       276
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER   OF HAZARD = $        87
    INITIAL COST/YEAR IMPACTS WITH  FACE                OF HAZARD = $        14
                                       TOTAL INITIAL ACCIDENT COST = $      392.

10. PROJECT LIFE =  20 YEARS        DISCOUNT RATE =  8.0 %
    KT =   9.818     KJ =    0.215     CRF =    0.102     KC   =  11.466

11. COST OF INSTALLATION          = $       650.
12. COST OF REPAIR  $ SU=      650  SD=      650  CU=      650  CD=      650  F=      650

13. MAINTENANCE COST PER YEAR     = $        10.
14. SALVAGE VALUE                 = $         0.

15. TOTAL PRESENT WORTH           = $     5,306.     ANNUALIZED $      540.
    HIGHWAY DEPARTMENT COST       = $       808.     ANNUALIZED $       82.

    INSTALLATION COST =             $       650.     ANNUALIZED $       66.
    REPAIR COST       =             $        60.     ANNUALIZED $        6.
    MAINTENANCE COST  =             $        98.     ANNUALIZED $       10.
    SALVAGE VALUE     =             $         0.     ANNUALIZED $        0.
    ACCIDENT COST     =             $     4,498.     ANNUALIZED $      458.
```

1. TITLE: LIGHT POLE 5-9

2. INITIAL TRAFFIC VOLUME = 5,000 VEHICLES PER DAY
TRAFFIC GROWTH RATE = 2.0 % PER YEAR DESIGN YEAR ADT = 7,430
LIMITING TRAFFIC VOLUME PER LANE = 10,000

3. UNDIVIDED HIGHWAY LANE(S) OF ADJACENT TRAFFIC = 1. LANE WIDTH = 12.0 F .

4. CURVATURE = 0.0 DEGREES GRADE (PERCENTAGE) = 0.0

5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)

	TRAFFIC VOLUME	BASELINE ENC.	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC.
ADJACENT	2,500	3.3250	1.00	1.00	1.0	3.3250
OPPOSING	2,500	3.3250	1.00	1.00	1.0	3.3250

6. DESIGN SPEED = 40 MPH ENCROACHMENT ANGLE = 17.2 SWATH WIDTH = 12.0

7. LATERAL PLACEMENT (A) = 9. FT.
LONGITUDINAL LENGTH (L) = 1. FT.
WIDTH OF OBSTACLE = 1. FT.

	ZONE1	ZONE2	ZONE3	
ADJACENT	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR
OPPOSING	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR

8. INITIAL COLLISION FREQUENCY = 0.007 IMPACTS PER YEAR
EXPECTED IMPACTS OVER PROJECT LIFE = 0.179
ADJACENT CFT= 0.0055 CF1 = 0.0002 CF2 = 0.0051 CF3 = 0.0002
OPPOSING CFT= 0.0018 CF4 = 0.0001 CF5 = 0.0016 CF6 = 0.0001

9. SEVERITY INDEX =

	SIDEUP	SIDEDOWN	UP CORNER	DOWN CORNER	FACE
SEVERITY INDEX =	3.80	3.80	3.80	3.80	3.80
ACCIDENT COST =	$ 48,800	$ 48,800	$ 48,800	$ 48,800	$ 48,800

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF HAZARD = $ 10
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF HAZARD = $ 3
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF HAZARD = $ 250
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF HAZARD = $ 79
INITIAL COST/YEAR IMPACTS WITH FACE OF HAZARD = $ 13
TOTAL INITIAL ACCIDENT COST = $ 356.

10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 8.0 %
KT = 9.818 KJ = 0.215 CRF = 0.102 KC = 11.466

11. COST OF INSTALLATION = $ 650.
12. COST OF REPAIR $ SU= 650 SD= 650 CU= 650 CD= 650 F= 6[illegible]

13. MAINTENANCE COST PER YEAR = $ 10.
14. SALVAGE VALUE = $ 0.

15. TOTAL PRESENT WORTH = $ 4,886. ANNUALIZED $ 498.
HIGHWAY DEPARTMENT COST = $ 803. ANNUALIZED $ 82.

INSTALLATION COST =	$ 650.	ANNUALIZED $	66.
REPAIR COST =	$ 54.	ANNUALIZED $	6.
MAINTENANCE COST =	$ 98.	ANNUALIZED $	10.
SALVAGE VALUE =	$ 0.	ANNUALIZED $	0.
ACCIDENT COST =	$ 4,083.	ANNUALIZED $	416.

```
 1. TITLE:    LIGHT POLE 5-10

 2. INITIAL TRAFFIC VOLUME =   5,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR    DESIGN YEAR ADT =     7,430
    LIMITING TRAFFIC VOLUME PER LANE  =   10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 FT.

 4. CURVATURE =   0.0 DEGREES          GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
              TRAFFIC   BASELINE   CURVATURE   GRADE     USER    TOTAL
              VOLUME      ENC.       FACTOR    FACTOR   FACTOR    ENC.
    ADJACENT   2,500     3.3250     1.00      1.00      1.0     3.3250
    OPPOSING   2,500     3.3250     1.00      1.00      1.0     3.3250

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)      =        10. FT.
    LONGITUDINAL LENGTH (L) =            1. FT.
    WIDTH OF OBSTACLE          =         1. FT.
                     ZONE1         ZONE2         ZONE3
    ADJACENT        0.0020        0.0256        0.0006   ENCROACHMENTS/YEAR
    OPPOSING        0.0020        0.0256        0.0006   ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =       0.007 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =      0.162
    ADJACENT     CFT=  0.0050  CF1 =  0.0002  CF2 =  0.0047  CF3 =  0.0002
    OPPOSING     CFT=  0.0016  CF4 =  0.0001  CF5 =  0.0015  CF6 =  0.0001

 9. SEVERITY INDEX =   3.80          3.80         3.80         3.80          3.80
                     SIDEUP       SIDEDOWN   UP CORNER  DOWN CORNER        FACE
    ACCIDENT COST = $   48,800  $   48,800  $   48,800  $   48,800   $   48,800
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE        OF HAZARD = $        10
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE      OF HAZARD = $         3
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER      OF HAZARD = $       227
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER    OF HAZARD = $        72
    INITIAL COST/YEAR IMPACTS WITH  FACE                 OF HAZARD = $        12
                                      TOTAL INITIAL ACCIDENT COST = $       323.

10. PROJECT LIFE =  20 YEARS        DISCOUNT RATE =  8.0 %
    KT =    9.818    KJ =    0.215    CRF =   0.102    KC  =  11.466

11. COST OF INSTALLATION            = $       650.
12. COST OF REPAIR  $ SU=      650  SD=     650  CU=     650  CD=     650  F=     650

13. MAINTENANCE COST PER YEAR       = $        10.
14. SALVAGE VALUE                   = $         0.

15. TOTAL PRESENT WORTH             = $     4,502.   ANNUALIZED $       459.
    HIGHWAY DEPARTMENT COST         = $       798.   ANNUALIZED $        81.

    INSTALLATION COST =               $       650.   ANNUALIZED $        66.
    REPAIR COST          =            $        49.   ANNUALIZED $         5.
    MAINTENANCE COST  =               $        98.   ANNUALIZED $        10.
    SALVAGE VALUE     =               $         0.   ANNUALIZED $         0.
    ACCIDENT COST     =               $     3,704.   ANNUALIZED $       377.
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APPENDIX N

"ROADSIDE" COMPUTER RUN
(BREAKAWAY EXAMPLE)

1. TITLE: LIGHT POLE (B/A)-5

2. INITIAL TRAFFIC VOLUME = 5,000 VEHICLES PER DAY
TRAFFIC GROWTH RATE = 2.0 % PER YEAR DESIGN YEAR ADT = 7,430
LIMITING TRAFFIC VOLUME PER LANE = 10,000

3. UNDIVIDED HIGHWAY LANE(S) OF ADJACENT TRAFFIC = 1. LANE WIDTH = 12.0 F..

4. CURVATURE = 0.0 DEGREES GRADE (PERCENTAGE) = 0.0

5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)

	TRAFFIC VOLUME	BASELINE ENC.	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC.
ADJACENT	2,500	3.3250	1.00	1.00	1.0	3.3250
OPPOSING	2,500	3.3250	1.00	1.00	1.0	3.3250

6. DESIGN SPEED = 40 MPH ENCROACHMENT ANGLE = 17.2 SWATH WIDTH = 12.0

7. LATERAL PLACEMENT (A) = 2. FT.
LONGITUDINAL LENGTH (L) = 1. FT.
WIDTH OF OBSTACLE = 1. FT.

	ZONE1	ZONE2	ZONE3	
ADJACENT	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR
OPPOSING	0.0020	0.0256	0.0006	ENCROACHMENTS/YEAR

8. INITIAL COLLISION FREQUENCY = 0.015 IMPACTS PER YEAR
EXPECTED IMPACTS OVER PROJECT LIFE = 0.363
ADJACENT CFT= 0.0114 CF1 = 0.0004 CF2 = 0.0105 CF3 = 0.0004
OPPOSING CFT= 0.0034 CF4 = 0.0001 CF5 = 0.0032 CF6 = 0.0001

9. SEVERITY INDEX =

	SIDEUP	SIDEDOWN	UP CORNER	DOWN CORNER	FACE
SEVERITY INDEX	1.50	1.50	1.50	1.50	1.50
ACCIDENT COST =	$ 2,538	$ 2,538	$ 2,538	$ 2,538	$ 2,53

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF HAZARD = $ 1
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF HAZARD = $ 0
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF HAZARD = $ 27
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF HAZARD = $ 8
INITIAL COST/YEAR IMPACTS WITH FACE OF HAZARD = $ 1
TOTAL INITIAL ACCIDENT COST = $ 38.

10. PROJECT LIFE = 20 YEARS DISCOUNT RATE = 8.0 %
KT = 9.818 KJ = 0.215 CRF = 0.102 KC = 11.466

11. COST OF INSTALLATION = $ 750.
12. COST OF REPAIR $ SU= 350 SD= 350 CU= 350 CD= 350 F= 350

13. MAINTENANCE COST PER YEAR = $ 10.
14. SALVAGE VALUE = $ 0.

15. TOTAL PRESENT WORTH = $ 1,338. ANNUALIZED $ 136.
HIGHWAY DEPARTMENT COST = $ 908. ANNUALIZED $ 92.

INSTALLATION COST =	$ 750.	ANNUALIZED $	76.
REPAIR COST =	$ 59.	ANNUALIZED $	6.
MAINTENANCE COST =	$ 98.	ANNUALIZED $	10.
SALVAGE VALUE =	$ 0.	ANNUALIZED $	0.
ACCIDENT COST =	$ 430.	ANNUALIZED $	44.

```
 1. TITLE:    LIGHT POLE (B/A)-10

 2. INITIAL TRAFFIC VOLUME =  10,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR    DESIGN YEAR ADT =   14,859
    LIMITING TRAFFIC VOLUME PER LANE  =    10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 FT.

 4. CURVATURE =   0.0 DEGREES           GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
              TRAFFIC   BASELINE   CURVATURE   GRADE    USER    TOTAL
              VOLUME    ENC.         FACTOR    FACTOR   FACTOR   ENC.
    ADJACENT  5,000     6.6500       1.00      1.00     1.0     6.6500
    OPPOSING  5,000     6.6500       1.00      1.00     1.0     6.6500

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)      =         2. FT.
    LONGITUDINAL LENGTH (L) =         1. FT.
    WIDTH OF OBSTACLE          =         1. FT.
                      ZONE1          ZONE2          ZONE3
    ADJACENT         0.0041         0.0511         0.0013  ENCROACHMENTS/YEAR
    OPPOSING         0.0041         0.0511         0.0013  ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =          0.030 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =        0.726
    ADJACENT     CFT=  0.0227  CF1 =  0.0008  CF2 =  0.0210  CF3 =  0.0009
    OPPOSING     CFT=  0.0069  CF4 =  0.0003  CF5 =  0.0064  CF6 =  0.0002

 9. SEVERITY INDEX =    1.50          1.50        1.50         1.50          1.50
                       SIDEUP        SIDEDOWN   UP CORNER   DOWN CORNER        FACE
    ACCIDENT COST = $     2,538  $     2,538  $     2,538  $     2,538  $     2,538
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE         OF HAZARD = $           2
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE       OF HAZARD = $           1
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER       OF HAZARD = $          53
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER     OF HAZARD = $          16
    INITIAL COST/YEAR IMPACTS WITH  FACE                  OF HAZARD = $           3
                                     TOTAL INITIAL ACCIDENT COST = $          75.

10. PROJECT LIFE =  20 YEARS          DISCOUNT RATE =  8.0 %
    KT =     9.818    KJ =     0.215    CRF =    0.102    KC   =  11.466

11. COST OF INSTALLATION            = $        750.
12. COST OF REPAIR  $ SU=       350  SD=      350  CU=      350  CD=      350  F=      350

13. MAINTENANCE COST PER YEAR       = $         10.
14. SALVAGE VALUE                   = $          0.

15. TOTAL PRESENT WORTH             = $      1,828.   ANNUALIZED $        186.
    HIGHWAY DEPARTMENT COST         = $        967.   ANNUALIZED $         98.

    INSTALLATION COST =               $        750.   ANNUALIZED $         76.
    REPAIR COST       =               $        119.   ANNUALIZED $         12.
    MAINTENANCE COST  =               $         98.   ANNUALIZED $         10.
    SALVAGE VALUE     =               $          0.   ANNUALIZED $          0.
    ACCIDENT COST     =               $        861.   ANNUALIZED $         88.
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 1. TITLE:    LIGHT POLE (B/A)-20

 2. INITIAL TRAFFIC VOLUME =  20,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR    DESIGN YEAR ADT =   29,719
    LIMITING TRAFFIC VOLUME PER LANE  =   10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 F .

 4. CURVATURE =   0.0 DEGREES            GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
              TRAFFIC   BASELINE   CURVATURE   GRADE     USER    TOTAL
              VOLUME      ENC.       FACTOR    FACTOR   FACTOR   ENC.
    ADJACENT  10,000     13.3000     1.00       1.00     1.0    13.3000
    OPPOSING  10,000     13.3000     1.00       1.00     1.0    13.3000

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)     =          2. FT.
    LONGITUDINAL LENGTH (L) =          1. FT.
    WIDTH OF OBSTACLE         =          1. FT.
                      ZONE1         ZONE2         ZONE3
    ADJACENT         0.0081        0.1022        0.0025   ENCROACHMENTS/YEAR
    OPPOSING         0.0081        0.1022        0.0025   ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =         0.059 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =       1.451
    ADJACENT     CFT=  0.0454  CF1 =  0.0017  CF2 =  0.0420  CF3 =  0.0018
    OPPOSING     CFT=  0.0137  CF4 =  0.0005  CF5 =  0.0127  CF6 =  0.0005

 9. SEVERITY INDEX =    1.50          1.50          1.50          1.50         1.50
                       SIDEUP       SIDEDOWN    UP CORNER   DOWN CORNER       FACE
    ACCIDENT COST = $    2,538  $     2,538  $     2,538  $     2,538  $     2,53
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE        OF HAZARD = $          4
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE      OF HAZARD = $          1
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER      OF HAZARD = $        107
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER    OF HAZARD = $         32
    INITIAL COST/YEAR IMPACTS WITH  FACE                 OF HAZARD = $          6
                                      TOTAL INITIAL ACCIDENT COST = $       150.

10. PROJECT LIFE =  20 YEARS        DISCOUNT RATE =  8.0 %
    KT =     9.818    KJ =     0.215    CRF =    0.102    KC   = 11.466

11. COST OF INSTALLATION               = $       750.
12. COST OF REPAIR  $ SU=       350  SD=      350  CU=      350  CD=      350  F=    350

13. MAINTENANCE COST PER YEAR          = $        10.
14. SALVAGE VALUE                      = $         0.

15. TOTAL PRESENT WORTH                = $     2,807.     ANNUALIZED $          286.
    HIGHWAY DEPARTMENT COST            = $     1,086.     ANNUALIZED $          111.

    INSTALLATION COST =                  $       750.     ANNUALIZED $           76.
    REPAIR COST       =                  $       237.     ANNUALIZED $           24.
    MAINTENANCE COST  =                  $        98.     ANNUALIZED $           10.
    SALVAGE VALUE     =                  $         0.     ANNUALIZED $            0.
    ACCIDENT COST     =                  $     1,721.     ANNUALIZED $          175.
```

```
 1. TITLE:    LIGHT POLE (B/A)-30

 2. INITIAL TRAFFIC VOLUME =  30,000 VEHICLES PER DAY
    TRAFFIC GROWTH RATE =  2.0 % PER YEAR    DESIGN YEAR ADT =   44,578
    LIMITING TRAFFIC VOLUME PER LANE  =  10,000

 3. UNDIVIDED HIGHWAY  LANE(S) OF ADJACENT TRAFFIC =   1.  LANE WIDTH = 12.0 FT.

 4. CURVATURE =    0.0 DEGREES            GRADE (PERCENTAGE) =   0.0

 5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)
              TRAFFIC  BASELINE  CURVATURE  GRADE    USER   TOTAL
              VOLUME     ENC.     FACTOR    FACTOR   FACTOR  ENC.
    ADJACENT  15,000    13.3000    1.00      1.00     1.0   13.3000
    OPPOSING  15,000    13.3000    1.00      1.00     1.0   13.3000

 6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE =  17.2  SWATH WIDTH =  12.0

 7. LATERAL PLACEMENT (A)     =          2. FT.
    LONGITUDINAL LENGTH (L) =          1. FT.
    WIDTH OF OBSTACLE         =          1. FT.
                       ZONE1        ZONE2        ZONE3
    ADJACENT          0.0081       0.1022       0.0025  ENCROACHMENTS/YEAR
    OPPOSING          0.0081       0.1022       0.0025  ENCROACHMENTS/YEAR

 8. INITIAL COLLISION FREQUENCY =        0.059 IMPACTS PER YEAR
    EXPECTED IMPACTS OVER PROJECT LIFE =      1.451
    ADJACENT     CFT=  0.0454  CF1 =  0.0017  CF2 =  0.0420  CF3 =  0.0018
    OPPOSING     CFT=  0.0137  CF4 =  0.0005  CF5 =  0.0127  CF6 =  0.0005

 9. SEVERITY INDEX =    1.50          1.50          1.50         1.50          1.50
                      SIDEUP      SIDEDOWN    UP CORNER  DOWN CORNER       FACE
    ACCIDENT COST = $     2,538  $     2,538  $     2,538  $     2,538  $    2,538
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM SIDE         OF HAZARD = $          4
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM SIDE       OF HAZARD = $          1
    INITIAL COST/YEAR IMPACTS WITH  UPSTREAM CORNER       OF HAZARD = $        107
    INITIAL COST/YEAR IMPACTS WITH  DOWNSTREAM CORNER     OF HAZARD = $         32
    INITIAL COST/YEAR IMPACTS WITH  FACE                  OF HAZARD = $          6
                                      TOTAL INITIAL ACCIDENT COST = $        150.

10. PROJECT LIFE =  20 YEARS        DISCOUNT RATE =  8.0 %
    KT =     9.818     KJ =     0.215    CRF =    0.102    KC   =  11.466

11. COST OF INSTALLATION              = $        750.
12. COST OF REPAIR  $ SU=      350  SD=     350  CU=      350  CD=     350  F=      350

13. MAINTENANCE COST PER YEAR        = $         10.
14. SALVAGE VALUE                    = $          0.

15. TOTAL PRESENT WORTH              = $      2,807.    ANNUALIZED $         286.
    HIGHWAY DEPARTMENT COST          = $      1,086.    ANNUALIZED $         111.

    INSTALLATION COST =                 $        750.    ANNUALIZED $          76.
    REPAIR COST        =                $        237.    ANNUALIZED $          24.
    MAINTENANCE COST   =                $         98.    ANNUALIZED $          10.
    SALVAGE VALUE      =                $          0.    ANNUALIZED $           0.
    ACCIDENT COST      =                $      1,721.    ANNUALIZED $         175.
```

1. TITLE: LIGHT POLE (B/A)-40

2. INITIAL TRAFFIC VOLUME = 40,000 VEHICLES PER DAY
TRAFFIC GROWTH RATE = 2.0 % PER YEAR   DESIGN YEAR ADT = 59,438
LIMITING TRAFFIC VOLUME PER LANE = 10,000

3. UNDIVIDED HIGHWAY LANE(S) OF ADJACENT TRAFFIC = 1. LANE WIDTH = 12.0 FT.

4. CURVATURE = 0.0 DEGREES   GRADE (PERCENTAGE) = 0.0

5. INITIAL ENCROACHMENT FREQUENCY = 0.0013300 * (TVeff ^ 1.000000)

	TRAFFIC VOLUME	BASELINE ENC.	CURVATURE FACTOR	GRADE FACTOR	USER FACTOR	TOTAL ENC.
ADJACENT	20,000	13.3000	1.00	1.00	1.0	13.3000
OPPOSING	20,000	13.3000	1.00	1.00	1.0	13.3000

6. DESIGN SPEED = 40 MPH   ENCROACHMENT ANGLE = 17.2   SWATH WIDTH = 12.0

7. LATERAL PLACEMENT (A) = 2. FT.
LONGITUDINAL LENGTH (L) = 1. FT.
WIDTH OF OBSTACLE = 1. FT.

	ZONE1	ZONE2	ZONE3	
ADJACENT	0.0081	0.1022	0.0025	ENCROACHMENTS/YEAR
OPPOSING	0.0081	0.1022	0.0025	ENCROACHMENTS/YEAR

8. INITIAL COLLISION FREQUENCY = 0.059 IMPACTS PER YEAR
EXPECTED IMPACTS OVER PROJECT LIFE = 1.451
ADJACENT CFT= 0.0454 CF1 = 0.0017 CF2 = 0.0420 CF3 = 0.0018
OPPOSING CFT= 0.0137 CF4 = 0.0005 CF5 = 0.0127 CF6 = 0.0005

9. SEVERITY INDEX =

	SIDEUP	SIDEDOWN	UP CORNER	DOWN CORNER	FACE
SEVERITY INDEX	1.50	1.50	1.50	1.50	1.50
ACCIDENT COST	$ 2,538	$ 2,538	$ 2,538	$ 2,538	$ 2,538

INITIAL COST/YEAR IMPACTS WITH UPSTREAM SIDE OF HAZARD = $ 4
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM SIDE OF HAZARD = $ 1
INITIAL COST/YEAR IMPACTS WITH UPSTREAM CORNER OF HAZARD = $ 107
INITIAL COST/YEAR IMPACTS WITH DOWNSTREAM CORNER OF HAZARD = $ 32
INITIAL COST/YEAR IMPACTS WITH FACE OF HAZARD = $ 6
TOTAL INITIAL ACCIDENT COST = $ 150.

10. PROJECT LIFE = 20 YEARS   DISCOUNT RATE = 8.0 %
KT = 9.818 KJ = 0.215 CRF = 0.102 KC = 11.466

11. COST OF INSTALLATION = $ 750.
12. COST OF REPAIR $ SU= 350 SD= 350 CU= 350 CD= 350 F= 3!

13. MAINTENANCE COST PER YEAR = $ 10.
14. SALVAGE VALUE = $ 0.

15. TOTAL PRESENT WORTH = $ 2,807. ANNUALIZED $ 286.
HIGHWAY DEPARTMENT COST = $ 1,086. ANNUALIZED $ 111.

INSTALLATION COST =	$ 750.	ANNUALIZED $	76.
REPAIR COST =	$ 237.	ANNUALIZED $	24.
MAINTENANCE COST =	$ 98.	ANNUALIZED $	10.
SALVAGE VALUE =	$ 0.	ANNUALIZED $	0.
ACCIDENT COST =	$ 1,721.	ANNUALIZED $	175.

APPENDIX O

BENEFIT-TO-COST RATIO ANALYSES RELOCATION AND BREAKAWAYEXAMPLE)

SLP2 (Plot)

(B/C) Analysis 2 LANE ROADWAY 'LIGHT POLES'

2 LANE ROADWAY LIGHT POLE S-2; S-10

Speed (mph)	ADT (vpd)	Countermeasure NON-BREAKAWAY	Severity Index (SI)	Annualized Benefit ($)		Annualized Installation and Repair Cost ($)				$\Delta_{BENEFIT}$	Δ_I	Δ_K	Δ_C	$\Delta B/\Delta C$
				Accident Cost Before	Accident Cost After	BEFORE Inst.	BEFORE Repair	AFTER Inst.	AFTER Repair					
40	5000	original 2' offset	3.8	843	0	0	11	0	0	—	—	—	—	—
40	5000	Relocate to 3'	3.8	843	758	0	11	66	10	85	66	-1	65	1.31
40	5000	Relocate to 4'	3.8	843	682	0	11	66	9	161	66	-2	64	2.52
40	5000	Relocate to 5'	3.8	843	617	0	11	66	8	226	66	-3	63	3.58
40	5000	Relocate to 6'	3.8	843	558	0	11	66	7	285	66	-4	62	4.59
40	5000	Relocate to 7'	3.8	843	506	0	11	66	7	337	66	-4	62	5.43
40	5000	Relocate to 8'	3.8	843	458	0	11	66	6	385	66	-5	61	6.31
40	5000	Relocate to 9'	3.8	843	416	0	11	66	6	427	66	-5	61	7.00
40	5000	Relocate to 10'	3.8	843	377	0	11	66	5	466	66	-6	60	7.76

Installation Cost : $1650
Repair Cost : $650

Haul Cost $10.0

B/C Analysis

2 LANE ROADWAY LIGHT POLE BREAKAWAY 5000 – 40000 ADT's

Speed (mph)	ADT (vpd)	Countermeasure Breakaway = B/A	Severity Index (SI)	Annualized Benefit ($)		Annualized Installation and Repair Cost ($)				$\Delta_{BENEFIT}$	Δ_I	Δ_K	Δ_C	$\Delta B/\Delta C$
				Accident Cost Before	Accident Cost After	BEFORE		AFTER						
						Inst.	Repair	Inst.	Repair					
40	5000	original 2' offset + B/A	1.5	843	44	0	11	76	6	799	76	-5	71	11.25
40	10000	original 2' offset + B/A	1.5	1685	88	0	22	76	12	1597	76	-10	66	24.19
40	20000	original 2' offset + B/A	1.5	3371	175	0	45	76	24	3196	76	-21	55	58.11
40	30000	original 2' offset + B/A	1.5	3371	175	0	45	76	24	3196	76	-21	55	58.11
40	40000	original 2' offset + B/A	1.5	3371	175	0	45	76	24	3196	76	-21	55	58.11

Installation Cost. $750
Repair Cost : $350

Maint: $10.0

APPENDIX P

REIMBURSEMENT LITERATURE REVIEW

REIMBURSEMENT LITERATURE REVIEW

Relocation of public utilities located in the highway right-of-way has been an important issue for many years. The following section includes a detailed summary of this issue taken from the publication entitled, "Selected Studies in Highway Law--Vol. 2," by Larry W. Thomas (45). It includes a discussion on the payments to public utilities for the relocation of their facilities in highway right-of-way.

INTRODUCTION

Two basic issues were addressed: the first was the extent to which either the State or the utility should pay the cost of relocation when the utility is required to move its facilities due to highway construction or improvements; the second was the reimbursement of States for payments to utilities pursuant to Title 23, Section 123 of the United States Code (U.S.C.). The first situation is strictly a matter between the utility and the State, county, or city, or an agency of one of those levels of government. When utility facilities are relocated, the utility may claim that the government which required the relocation must pay for the relocation expenses. Unless there is a specific statutory authority for such payments, the utility usually will have to bear the costs. The second situation is concerned with the reimbursement of States by the Federal Highway Administration (FHWA) where the States are paying the cost of utility relocation from the highway right-of-way as part of the highway construction project.

The term "utilities" as used by Thomas (45) means a business or service that is engaged in regularly providing the public with a commodity that it requires, such as electricity, gas, water, transportation, telephone, or telegraph service. The federal regulations for Title 23, Section 123 of the U.S.C. define the term as follows:

Utility shall mean and include all privately, publicly, or cooperatively owned lines, facilities, and systems for producing, transmitting or distributing communications, power, electricity, light, heat, gas, oil, crude products, water, steam, waste, storm water not connected with highway drainage, and other similar commodities, including publicly owned fire and police signal systems and street lighting systems, which directly or indirectly serve the public or any part thereof. The term "utility" shall also mean the utility company, inclusive of any wholly owned or controlled subsidiary.

Although a few State statutes may distinguish between public and private utilities, the type of ownership does not appear to be a significant factor on the legal issues with payment of relocation costs.

The term "reimbursement" is somewhat misleading in that its application is more precise in the discussion of reimbursement of States by the FHWA. Where the State, pursuant to Title 23, Section 123 of the U.S.C.,pays the cost of relocation of utility facilities, the States are reimbursed pro-rata for their expense in the same proportion as the percentage of Federal funds participating in the project.

The term "relocation" means a utility, located in the highway proper or in the highway right-of-way, has had to adjust, move, or relocate its facilities in order for the highway agency to complete the highway project.

At the time, Thomas found that reimbursement of relocation cost of utilities was sanctioned for Interstate Highway projects in fifteen States. Such payments were authorized on all Federal-aid highway projects in six States. Seven States paid utility relocation cost on certain types of State highways. However, no statutory authority existed for paying such cost in eleven States.

COMPENSATION FOR TAKING OR DAMAGING OF UTILITY EASEMENT OR PROPERTY

Majority View

Utility facilities may be located in the highway right-of-way pursuant to statute or written permission such as a license, franchise, or permit. The method by which a utility is able to locate its facilities within highway right-of-way is important in determining whether a utility must be paid for relocating.

When a utility is located entirely on its own private right-of-way or easement, the courts have been consistent in requiring the highway agency to either purchase or condemn the utility's property interest before compelling the relocation of facilities. The case which set the precedent came from Commonwealth vs. Means & Russell Iron Co., (299 Ky. 465, 185 S.W. 2d 960 1945). It stated:

> "The rule is now as it was then, when the government requires the relocation of a perpetual easement for the public convenience its owner is entitled to compensation in the form of damages, which may be determined by the actual cost of relocation."

Minority View

A utility cannot be required to relocate its facilities which are located on its own property by the State's police power. However, there have been cases which awarded compensation for the taking of a utility's property, when the utility's interest did not rise to the level of a fee or an easement. The cases occurred when the utility was compelled to remove its facilities to a new location outside of the highway right-of-way. It was stated that this complete abrogation of the privilege to be located in the highway right-of-way constituted a taking.

Damages

It seems there have been few court decisions which have elaborated on the issue of what constitutes "just compensation". But, it appears to be the value of any real estate taken plus the cost of relocating the facilities.

The courts have held consistently that where the utility's facilities are located on private property, the highway agency may not compel them to be relocated without paying just compensation.

RELOCATION WITHOUT PAYMENT PURSUANT TO THE POLICE POWER WHERE THE UTILITY HAS NO PROPERTY INTEREST

State's Authority to Require Relocation of Utilities

In most situations which involve relocation of utilities, the facilities will not be located on private property, instead, they will be located in the highway right-of-way, usually by permission of a statute, franchise, license, or permit.

The authority of the State to regulate its streets and highways is well established. The utilities located along the streets and highways are also included within the scope of this authority. This includes the right to require the utility to relocate its facilities when required by highway construction or improvements. When utilities are located in highways or highway right-of-way by virtue of a statute or franchise, they require no vested right to any specific location in the right-of-way.

There are limitations on the State's requiring relocation of facilities pursuant to the doctrine of the police power. One such limitation is that the State must be acting reasonably. The key to the scope of police power is reasonableness, because the Constitution does not require compensation where there is an appropriate exercise of power. It does define a taking in eminent domain as compensable. In addition to being reasonable, the action of the public authority that is requiring relocation must be "governmental in nature"; that is, it must be for a governmental purpose. Generally, the decision to relocate utility facilities in order to accommodate highway construction is considered a recognizable, traditional, governmental function.

Another limitation on the government's right to compel relocation is that it may not discriminate unfairly among utilities, and any distinction between utilities involving relocation cost or reimbursement must have a reasonable, rational basis.

Finally, it appears to be a general rule, that, unless a statute authority authorizes payment of relocation cost, a State, county, or municipal agency may not enter into a contract that intends to bind the agency to paying such cost.

<u>No Liability for Relocation Cost in the Absence of Statute</u>

In the absence of statute, the courts have consistently held, that, if utility facilities are required to be relocated due to highway construction or improvements, the utility, and not the State or highway agency, must bear the cost incurred in relocating.

One reason for this common law rule is that, because utilities occupy the highways free of cost, they should not be entitled to compensation when they are required to relocate their facilities in order to accommodate highway improvements.

Another reason is the courts believe that the utilities have an implied obligation to relocate their property at their own expense when a governmental use of the streets renders the relocation necessary.

Effect of Franchises or Other Agreements

The fact that the utility has been allowed by virtue of a franchise or an agreement to occupy a highway right-of-way does not create any property right that must be compensated when the utility is required to relocate its facilities. Even though the utility may have a franchise, license, or permit, the general rule is that the utility must relocate its facilities at its own expense when the changes resulted from public necessity.

A "franchise" is defined as a special privilege conferred by the State on an individual or corporation to do that which a citizen cannot do by common right. Unlike a license, a franchise usually does not create an interest in land, even though the use of the franchise requires the occupancy of land.

Effect of Municipal Ownership

It is generally known that in the absence of State practice or statute, municipally owned utilities must bear the cost to relocate their facilities in the right-of-way when they are required to do so by State highway construction. There are several reasons for this general conclusion. First, the State has jurisdiction over the highways even though the "fee" title to the street or highway may be vested in the municipality. However, in a few cases, the municipality has been reimbursed or compensated on the basis that it holds title to its streets. Second, in the absence of State practice or statute, no compensation is required to be paid to a municipally owned utility, because it is considered by the courts to be exercising a "proprietary" function when it goes into the utility business. A proprietary service is one conducted for a fee or charge for the benefit of the community. When performing a proprietary service, the municipality is considered to have the rights and obligations of a private corporation.

Effect of Location on Toll Road

When a utility is located in or along a toll road, the toll road is a "public highway" for the purpose of determining that the utility must pay the cost of relocation. Unless a provision for the toll road authority exists, the utility may be required to relocate its facilities at its own expense.

REIMBURSEMENT OF STATES FOR RELOCATION PAYMENTS MADE TO UTILITIES: TITLE 23, U.S.C., SECTION 123

As stated earlier, the general rule is that a state or highway agency is not required, in the absence of statute, to pay a utility its cost to relocate its facilities located in the highway or highway right-of-way due to highway construction or improvements. In 1956, the Congress authorized the FHWA to reimburse the States for utility relocation cost in the same proportion that Federal funds were expanded on the project.

Eligibility for Reimbursement

On Federal-aid primary or secondary systems or the Interstate system, the States may be reimbursed for the cost of relocating utility facilities when part of the highway construction project in the same proportion as the amount of Federal funds spent on the project. The reimbursement may be made whether the utility facilities are publicly, privately, or cooperatively owned.

Reimbursement Where Utility Has a Property Right

First, reimbursement may occur on a pro-rata basis if the utility has the right to occupy the site. The regulations authorize reimbursement

> "where the utility has the right of occupancy in its existing location by reason of holding fee, an easement, or other real property interest, the damaging or taking of which is compensable in eminent domain."

A "fee" is equivalent to "fee simple" or "fee simple absolute" which is the largest estate in terms of ownership. An "easement" is the right to use the land of another for a special purpose.

Reimbursement Where Payment Is Made Pursuant to Suitable State Law

Second, the State may be reimbursed for utility relocation costs

> "where the utility occupies either publicly or privately owned land or public right-of-way, and the State's payment of the costs of relocation is made pursuant to State law, and does not violate a legal contract between the utility and the State, provided an affirmative finding has been made by FHWA that such a law forms a suitable basis for Federal-aid fund participation under the provisions of 23 U.S.C. 123."

Reimbursement Where Utility Is owned by State Agency or olitical Subdivision

The third category for reimbursement is

> "where the utility which occupies publicly owned lands or public right-of-way is owned by an agency or political subdivision is not required by law or agreement to relocate its facilities at its own expense, provided the State has furnished a statement to FHWA establishing and/or citing its legal authority or obligation to make such payments, and an affirmative finding has been made by FHWA that such a statement forms a suitable basis for Federal-aid participation under the provisions of 23 U.S.C."

SUMMARY AND CONCLUSIONS (by Thomas)

When utilities located in or along State highways or right-of-way must be relocated, the interest held by the utility must be analyzed in order to determine whether the State or the utility must bear the cost.

In the case where utilities are located on property that the utility has acquired, such as an easement or right-of-way, the rule is that the State must pay the relocation cost. This corresponds to highway construction or improvement which requires the utilities to relocate. The reason is that the agency's action constitutes a taking or damaging of private property for public use.

A utility is more likely to locate its facilities with accordance to a franchise, permit, license, or other agreement. Unless there is statutory authority for paying relocation cost, the general rule is that the utility must bear its own cost when required to relocate or remove its facilities due to highway improvements.

Most State statutes regarding reimbursement were enacted in order to take advantage of Title 23 U.S.C. Section 123, which allows the FHWA to reimburse States on a pro-rata basis for utility relocation cost as part of the highway construction contract.

FINAL COMMENTS

The Federal Highway Administration has a policy which deals with utility relocation and reimbursement. It is part of the Federal-Aid Highway Program Manual FHPM 6-6-3-1, as shown in Appendix R. The subsection entitled, "Utility Relocations, Adjustments, and Reimbursement," was included for the purpose of reference material.

APPENDIX Q.

REIMBURSEMENT POLICIES TO UTILITIES (QUESTIONNAIRE #2)

University of
Nebraska
Lincoln

Department of
Civil Engineering
W348 Nebraska Hall
Lincoln, NE 68588-0531

August 16, 1989

Dear Mr. :

The University of Nebraska is currently conducting a research study for the Nebraska Department of Roads (NDOR), entitled "Economic and Safety Considerations for Establishing Minimum Lateral Obstacle Clearance Policies for Utility Facilities in Urban Areas." While the emphasis will be on urban roads, the study will also include rural roads.

One of the research tasks is to conduct a review of other states' utility reimbursement policies for highway construction relocations. This review includes such utilities such as electric power, telephone, pipeline, cable tv, etc. The enclosed Questionnaire addresses a number of issues concerning utility reimbursement policies.

We would greatly appreciate a response by September 6, 1989. If you do not intend to participate, will you please inform us of this so that we can complete the summary of this questionnaire as soon as possible.

I would like to take this opportunity to thank you in advance for your assistance and time in addressing a critical safety issue.

Respectfully,

Dr. Edward R. Post, Ph.D., P.E.
Professor

ERP/wge

cc: Mr. Fred Gunderson
NDOR Project Manager

enclosures (1)

QUESTIONNAIRE

UTILITY REIMBURSEMENT POLICY FOR HIGHWAY CONSTRUCTION LOCATIONS

Nebraska Department of Roads
University of Nebraska-Lincoln

August 11, 1989

State Agency ______________________________

Name of Respondent ______________________________

Address ______________________________

____

____

Phone ______________________________

1. Does your state have a specific policy regarding reimbursement to utilities for highway construction related relocations?

   Yes _______ No _______

2. Is your policy set by:

   State Law _______
   Local Ordinances _______
   Franchise Agreement _______

3. Does your state follow FHPM 6-6-3-1 in determining eligible costs?

   Yes _______ No _______

4. Do you use Federal Funds for utility relocations?

   Yes _______ No _______

   a) On an annual basis, what approximate percentage of reimbursable utility costs do you utilize from Federal Funds?

      1) Less that 20% _______
      2) 20% to 40% _______
      3) 40% to 60% _______
      4) 60% to 80% _______
      5) More than 80% _______

b) Is cost a criteria for use of Federal Funds?

Yes ______ No ______

1) If the answer to b) was yes, at what cost range do you pursue Federal Funds?

____

5. Does your state use the alternate procedures as outlined in FHPM 6-6-3-1?

Yes ______ No ______

6. Are utility relocation costs reimbursable to utilities for relocations required on public R.O.W.?

Yes ______ No ______

7. Does your state issue permits to occupy public R.O.W.?

Yes ______ No ______

8. Does your state grant easements to utilities on public R.O.W.?

Yes ______ No ______

9. Does your state grant franchise rights to utilities on public R.O.W.?

Yes ______ No ______

10. Does your state charge a fee to provide the services described in questions 7, 8 or 9?

Yes ______ No ______

11. Does the state's reimbursement policy differ for various types of utilities (i.e. electric power, telephone, pipeline, or cable tv)?

Yes ______ No ______

12. Does your state allow utilities to occupy your public R.O.W.?

Yes ______ No ______

13. Does your reimbursement policy vary for different roadway classifications?

Yes ______ No ______

14. Has your state encountered an uncooperative utility (eg. which refused to relocate)?

Yes ______ No ______

15. Is your state required to provide advance notice of projects to utilities?

Yes ______ No ______

16. Does your state allow concurrent relocation construction by utilities during highway construction?

Yes ______ No ______

17. Does your state have a state-wide 1-Call System for the location of utilities?

Yes ______ No ______

18. Does your state require contractors to use the 1-Call System?

Yes ______ No ______

19. Does your state participate in the 1-Call System?

Yes ______ No ______

RETURN COMPLETED QUESTIONNAIRE TO:

Edward R. Post, Ph.D., P.E.
Professor of Civil Engineering
University of Nebraska-Lincoln
W348 NH
Lincoln, NE 68588-0531
Telephone No. 402-472-5017
Fax No. 402-472-2410

APPENDIX R.

FEDERAL-AID HIGHWAY PROGRAM MANUAL FHPM 6-6-3-1

Transmittal 426
November 11, 1988
HNG-12

1. PURPOSE. **To prescribe the policies, procedures, and reimbursement provisions for the adjustment and relocation of utility facilities on Federal-aid or direct Federal projects.*

2. AUTHORITY. *23 U.S.C. 101, 109, 111, 116, 123, and 315; 23 CFR 1.23 and 1.27; 49 CFR 1.48(b); and Executive Order 11990, 42 FR 26961 (May 24, 1977).*

3. APPLICABILITY

   a. *The provisions of this regulation apply to reimbursement claimed by a State highway agency (SHA) for costs incurred under an approved and properly executed highway agency (HA)/utility agreement and for payment of costs incurred under all Federal Highway Administration (FHWA)/utility agreements.*

* Italicized material is published in 23 CFR 645A.

b. *Procedures on the accommodation of utilities are set forth in Federal-Aid Highway Program Manual (FHPM) 6-6-3-2, Accommodation of Utilities.*

c. *When the lines or facilities to be relocated or adjusted due to highway construction are privately owned, located on the owner's land, devoted exclusively to private use and not directly or indirectly serving the public, the provisions of the FHWA's right-of-way procedures in FHPM Volume 7, Right-of-Way and Environment, apply. When applicable, under the foregoing conditions, the provisions of this regulation may be used as a guide to establish a cost-to-cure.*

d. *The FHWA's reimbursement to the SHA will be governed by State law (or State regulation) or the provisions of this regulation, whichever is more restrictive. When State law or regulation differs from this regulation, a determination shall be made by the SHA subject to the concurrence of the* FHWA Division Administrator *as to which standards will govern, and the record documented accordingly, for each relocation encountered.*

e. *For direct Federal projects, all references herein to the SHA or HA are inapplicable, and it is intended that the FHWA be considered in the relative position of the SHA or HA.*

4. DEFINITIONS. *For the purposes of this directive, the following definitions shall apply:*

a. *Authorization - for Federal-aid projects authorization to the SHA by the FHWA* Division Administrator *or for direct Federal projects authorization to the utility by the FHWA* Division Engineer *to proceed with any phase of a project. The date of authorization establishes the date of eligibility for Federal funds to participate in the costs incurred on that phase of work.*

b. *Betterment - any upgrading of the facility being relocated that is not attributable to the highway construction and is made solely for the benefit of and at the election of the utility.*

c. *Cost of Relocation - the entire amount paid by or on behalf of the utility properly attributable to the relocation after deducting from that amount any increase in value of the new facility, and any salvage derived from the old facility.*

d. *Cost of Removal* - *the amount expended to remove utility property including the cost of demolishing, dismantling, removing, transporting, or otherwise disposing of utility property and of cleaning up to leave the site in a neat and presentable condition.*

e. *Cost of Salvage* - *the amount expended to restore salvaged utility property to usable condition after its removal.*

f. *Direct Federal Projects* - *highway projects such as projects under the Federal Lands Highways Program which are under the direct administration of the FHWA.*

g. *Highway Agency (HA)* - *that department, commission, board, or official of any State or political subdivison thereof, charged by its law with the responsibility for highway administration.*

h. *Indirect or Overhead Costs* - *those costs which are not readily identifiable with one specific task, job, or work order. Such costs may include indirect labor, social security taxes, insurance, stores expense, and general office expenses. Costs of this nature generally are distributed or allocated to the applicable job or work orders, other accounts and other functions to which they relate. Distribution and allocation is made on a uniform basis which is reasonable, equitable, and in accordance with generally accepted cost accounting practices.*

i. *Relocation* - *the adjustment of utility facilities required by the highway project. It includes removing and reinstalling the facility, including necessary temporary facilities, acquiring necessary right-of-way on the new location, moving, rearranging or changing the type of existing facilities and taking any necessary safety and protective measures. It shall also mean constructing a replacement facility that is both functionally equivalent to the existing facility and necessary for continuous operation of the utility service, the project economy, or sequence of highway construction.*

j. *Salvage Value* - *the amount received from the sale of utility property that has been removed or the amount at which the recovered material is charged to the utility's accounts, if retained for reuse.*

k. *<u>State Highway Agency</u> - the highway agency of one of the 50 States, the District of Columbia, or Puerto Rico.*

l. *<u>Use and Occupancy Agreement</u> - the document (written agreement or permit) by which the HA approves the use and occupancy of highway right-of-way by utility facilities or private lines.*

m. *<u>Utility</u> - a privately, publicly, or cooperatively owned line, facility or system for producing, transmitting, or distributing communications, cable television, power, electricity, light, heat, gas, oil, crude products, water, steam, waste, storm water not connected with highway drainage, or any other similar commodity, including any fire or police signal system or street lighting system, which directly or indirectly serves the public. The term utility shall also mean the utility company inclusive of any wholly owned or controlled subsidiary.*

n. *<u>Work Order System</u> - a procedure for accumulating and recording into separate accounts of a utility all costs to the utility in connection with any change in its system or plant.*

5. <u>ELIGIBILITY</u>

a. *When requested by the SHA, Federal funds may participate, subject to the provisions of paragraph 3d of this section and at the pro rata share applicable, in an amount actually paid by an HA for the costs of utility relocations. Federal funds may participate in safety corrective measures made under the provisions of paragraph 5k of this section. Federal funds may also participate for relocations necessitated by the actual construction of a highway project and under one or more of the following conditions when:*

(1) *the SHA certifies that the utility has the right of occupancy in its existing location because it holds the fee, an easement, or other real property interest, the damaging or taking of which is compensable in eminent domain,*

(2) *the utility occupies privately or publicly owned land, including public road or street right-of-way, and the SHA certifies that the payment by the HA is*

made pursuant to a law authorizing such payment in conformance with the provisions of 23 U.S.C. 123, and/or

(3) the utility occupies publicly owned land, including public road and street right-of-way, and is owned by a public agency or political subdivision of the State, and is not required by law or agreement to move at its own expense, and the SHA certifies that the HA has the legal authority or obligation to make such payments.

b. On projects which the SHA has the authority to participate in project costs, Federal funds may not participate in payments made by a political subdivision for relocation of utility facilities, other than those proposed under the provisions of paragraph 5k of this section, when State law prohibits the SHA from making payment for relocation of utility facilities.

c. On projects which the SHA does not have the authority to participate in project costs, Federal funds may participate in payments made by a political subdivision for relocation of utility facilities necessitated by the actual construction of a highway project when the SHA certifies that such payment is based upon the provisions of paragraph 5a of this section and does not violate the terms of a use and occupancy agreement, or legal contract, between the utility and the HA or for utility safety corrective measures under the provisions of paragraph 5k of this section.

d. Federal funds are not eligible to participate in any costs for which the utility contributes or repays the HA, except for utilities owned by the political subdivision on projects which qualify under the provisions of paragraph 5c of this section in which case the costs of the utility are considered to be costs of the HA.

e. The FHWA may deny Federal fund participation in any payments made by a HA for the relocation of utility facilities when such payments do not constitute a suitable basis for Federal fund participation under the provisions of Title 23, U.S.C.

f. *The rights of any public agency or political subdivision of a State under contract, franchise, or other instrument or agreement with the utility, pertaining to the utility's use and occupancy of publicly owned land, including public road and street right-of-way, shall be considered the rights of the SHA in the absence of State law to the contrary.*

g. *In lieu of the individual certifications required by paragraphs 5a and c, the SHA may file a statement with the FHWA* Division Administrator *setting forth the conditions under which the SHA will make payments for the relocation of utility facilities. The FHWA* Division Administrator *may approve Federal fund participation in utility relocations proposed by the SHA under the conditions of the statement when the FHWA* Regional Administrator *has made an affirmative finding that such statement and conditions form a suitable basis for Federal fund participation under the provisions of 23 U.S.C. 123. [OMB Control Number 2125-0515]*

h. *Federal funds may not participate in the cost of relocations of utility facilities made solely for the benefit or convenience of a utility, its contractor, or a highway contractor.*

i. *When the advance installation of new utility facilities crossing or otherwise occupying the proposed right-of-way of a planned highway project is underway, or scheduled to be underway, prior to the time such right-of-way is purchased by or under control of the HA, arrangements should be made for such facilities to be installed in a manner that will meet the requirements of the planned highway project. Federal funds are eligible to participate in the additional cost incurred by the utility that are attributable to, and in accommodation of, the highway project provided such costs are incurred subsequent to authorization of the work by the FHWA* Division Administrator. *Subject to the other provisions of this directive, Federal participation may be approved under the foregoing circumstances when it is demonstrated that the action taken is necessary to protect the public interest and the adjustment of the facility is necessary by reason of the actual construction of the highway project.*

j. *Federal funds are eligible to participate in the costs of preliminary engineering and allied services for utilities, the acquisition of replacement right-of-way for utilities, and the physical construction work associated with utility relocations. Such costs must be incurred by or on behalf of a utility after the date the work is included in an approved program and after the FHWA* Division Administrator *has authorized the SHA to proceed in accordance with FHPM 6-3-2-2, Federal-Aid Programs Approval and Project Authorization.*

k. *Federal funds may participate in projects solely for the purpose of implementing safety corrective measures to reduce the roadside hazards of utility facilities to the highway user. Safety corrective measures should be developed in accordance with the provisions of FHPM 6-6-3-2, paragraph 6k.*

6. PRELIMINARY ENGINEERING

a. *As mutually agreed to by the HA and utility, and subject to the provisions of paragraph (6b) of this section, preliminary engineering activities associated with utility relocation work may be done by:*

(1) *the HA's or utility's engineering forces;*

(2) *an engineering consultant selected by the HA, after consultation with the utility, the contract to be administered by the HA; or,*

(3) *an engineering consultant selected by the utility, with the approval of the HA, the contract to be administered by the utility.*

b. *When a utility is not adequately staffed to pursue the necessary preliminary engineering and related work for the utility relocation, Federal funds may participate in the amount paid to engineers, architects, and others for required engineering and allied services provided such amounts are not based on a percentage of the cost of relocation. When Federal participation is requested by the SHA in the cost of such services, the utility and its consultant shall agree in writing as to the services to be provided and the fees and arrangements for the services. Federal funds may participate in the cost of* *such services performed under existing written continuing contracts when it is demonstrated that such work is performed regularly for the utility in its own work and that the costs are reasonable. Prior approval by the FHWA* Division Administrator *of consulting services is necessary, except the FHWA* Division Administrator *may forgo preaward review and/or approval of any proposed consultant contract which is not expected to exceed $10,000.*

c. *The procedures in FHPM 1-7-2, Administration of Negotiated Contracts, may be used as a guide for reviewing proposed consultant contracts.*

7. <u>RIGHT-OF-WAY</u>

a. *Federal participation may be approved for the cost of replacement right-of-way provided:*

(1) *the utility has the right of occupancy in its existing location because it holds the fee, an easement, or another real property interest, the damaging or taking of which is compensable in eminent domain, or the acquisition is made in the interest of project economy or is necessary to meet the requirements of the highway project, and*

(2) *There will be no charge to the project for that portion of the utility's existing right-of-way being transferred to the HA for highway purposes.*

b. *The utility shall determine and make a written valuation of the replacement right-of-way that it acquires in order to justify amounts paid for such right-of-way. This written valuation shall be accomplished prior to negotiation for acquisition.*

c. *Acquisition of replacement right-of-way by the HA on behalf of a utility or acquisition of nonoperating real property from a utility shall be in accordance with the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (42 U.S.C. 4601 <u>et seq</u>.) and applicable right-of-way procedures in FHPM Volume 7, Right-of-Way and Environment.*

d. *When the utility has the right-of-occupancy in its existing location because it holds the fee, an easement, or another real property interest, and it is not necessary by reason of the highway construction to adjust or replace the facilities located thereon, the taking of and damage to the utility's real property, including the disposal or removal of such facilities, may be considered a right-of-way transaction in accordance with provisions of the applicable right-of-way procedures in FHPM Volume 7, Right-of-Way and Environment.*

8. AGREEMENTS AND AUTHORIZATIONS

a. *On Federal-aid and direct Federal projects involving utility relocations, the utility and the HA shall agree in writing on their separate responsibilities for financing and accomplishing the relocation work. When Federal participation is requested, the agreement shall incorporate this directive by reference and designate the method to be used for performing the work (by contract or force account) and for developing relocation costs. The method proposed by the utility for developing relocation costs must be acceptable to both the HA and the FHWA* Division Administrator. *The preferred method for the development of relocation costs by a utility is on the basis of actual direct and related indirect costs accumulated in accordance with a work order accounting procedure prescribed by the applicable Federal or State regulatory body.*

b. *When applicable, the written agreement shall specify the terms and amounts of any contribution or repayments made or to be made by the utility to the HA in connection with payments by the HA to the utility under the provisions of paragraph 5.*

c. *The agreement shall be supported by plans, specifications when required, and itemized cost estimates of the work agreed upon, including appropriate credits to the project, and shall be sufficiently informative and complete to provide the HA and the FHWA* Division Administrator *with a clear description of the work required.*

d. *When the relocation involves both work to be done at the HA's expense and work to be done at the expense of the utility, the written agreement shall state the share to be borne by each party.*

e. *In the event there are changes in the scope of work, extra work or major changes in the planned work covered by the approved agreement, plans, and estimates, Federal participation shall be limited to costs covered by a modification of the agreement, a written change, or extra work order approved by the HA and the FHWA* Division Administrator.

f. *When the estimated cost to the HA of proposed utility relocation work on a project for a specific utility company is $25,000 or less, the FHWA* Division Administrator *may approve an agreement between the HA and the utility for a lump-sum payment without later confirmation by audit of actual costs. Lump-sum agreements in excess of $25,000 may be approved when the FHWA* Regional Administrator *finds that this method of developing costs would be in the best interest of the public.*

g. *Except as otherwise provided by paragraph 8(h), authorization by the FHWA* Division Administrator *to the SHA to proceed with the physical relocation of a utility's facilities may be given after:*

(1) *the utility relocation work, or the right-of-way, or physical construction phase of the highway construction work is included in an approved program,*

(2) *the appropriate environmental evaluation and public hearing procedures required by 23 CFR 771, Environmental Impact and Related Procedures, have been satisfied, and*

(3) *the FHWA* Division Administrator *has reviewed and approved the plans, estimates, and proposed or executed agreements for the utility work and is furnished a schedule for accomplishing the work.*

h. *The FHWA* Division Administrator *may authorize the physical relocation of utility facilities before the requirements of paragraph 8g(2) are satisfied when the relocation or adjustment of utility facilities meets the requirements of paragraph 5i.*

i. *Whenever the FHWA* Regional Administrator *has authorized right-of-way acquisition under the hardship and protective buying provisions of FHPM Volume 7, Chapter 2, The Acquisition Function, the FHWA* Division Administrator *may authorize the physical relocation of utility facilities located in whole or in part on such right-of-way.*

j. *When all efforts by the HA and utility fail to bring about written agreement of their separate responsibilities under the provisions of this directive, the SHA shall submit its proposal and a full report of the circumstances to the FHWA. Conditional authorizations for the relocation work to proceed may be given by the FHWA* Division Administrator *to the SHA with the understanding that Federal funds will not be paid for work done by the utility until the SHA proposal has been approved by the FHWA* Washington Headquarters Office.

k. *The FHWA* Division Administrator *will consider for approval any special procedure under State law, or appropriate administrative or judicial order, or under blanket master agreements with the utilities, that will fully accomplish all of the foregoing objectives and accelerate the advancement of the construction and completion of projects.*

9. <u>CONSTRUCTION</u>

a. *The FHPM 6-4-1-14, Contract and Force Account, (Justification Required for Force Account Work), states that it is cost-effective for certain utility adjustments to be performed by a utility with its own forces and equipment, provided the utility is qualified to perform the work in a satisfactory manner. This cost-effectiveness finding covers minor work on the utility's existing facilities routinely performed by the utility with its own forces. When the utility is not adequately staffed and equipped to perform such work with its own forces and equipment at a time convenient to and in coordination with the associated highway construction, such work may be done by:*

(1) *a contract awarded by the HA or utility to the lowest qualified bidder based on appropriate solicitation,*

(2) inclusion as part of the HA's highway construction contract let by the HA as agreed to by the utility,

(3) an existing continuing contract, provided the costs are reasonable, or

(4) a contract for low-cost incidental work, such as tree trimming and the like, awarded by the HA or utility without competitive bidding, provided the costs are reasonable.

(b) When it has been determined under FHPM 6-4-1-14 that the force account method is not the most cost-effective means for accomplishing the utility adjustment, such work is to be done under competitive bid contracts as described in paragraphs 9(a)(1) and (2) or under an existing continuing contract provided it can be demonstrated this is the most cost-effective method.

(c) Costs for labor, materials, equipment, and other services furnished by the utility shall be billed by the utility directly to the HA. The special provisions of contracts let by the utility or the HA shall be explicit in this respect. The costs of force account work performed for the utility under a contract let by the HA shall be reported separately from the costs of other force account and contract items on the highway project.

10. COST DEVELOPMENT AND REIMBURSEMENT [OMB Control Number 2125-0519]

a. Developing and Recording Costs

(1) All utility relocation costs shall be recorded by means of work orders in accordance with an approved work order system except when another method of developing and recording costs, such as lump-sum agreement, has been approved by the HA and the FHWA. Except for work done under contracts, the individual and total costs properly reported and recorded in the utility's accounts in accordance with the approved method for developing such costs, or the lump-sum agreement, shall constitute the maximum amount on which Federal participation may be based.

(2) *Each utility shall keep its work order system or other approved accounting procedure in such a manner as to show the nature of each addition to or retirement from a facility, the total costs thereof, and the source or sources of cost. Separate work orders may be issued for additions and retirements. Retirements, however, may be included with the construction work order provided that all items relating to retirements shall be kept separately from those relating to construction.*

b. *Direct Labor Costs*

(1) *Salaries and wages, at actual or average rates, and related expenses paid by the utility to individuals for the time worked on the project are reimbursable when supported by adequate records. This includes labor associated with preliminary engineering, construction engineering, right-of-way, and force account construction.*

(2) *Salaries and expenses paid to individuals who are normally part of the overhead organization of the utility may be reimbursed for the time worked directly on the project when supported by adequate records and when the work performed by such individuals is essential to the project and could not have been accomplished as economically by employees outside the overhead organization.*

(3) *Amounts paid to engineers, architects and others for services directly related to projects may be reimbursed.*

c. *Labor Surcharges*

(1) *Labor surcharges include worker compensation insurance, public liability and property damage insurance, and such fringe benefits as the utility has established for the benefit of its employees. The cost of labor surcharges will be reimbursed at actual costs to the utility, or, at the option of the utility, average rates which are representative of actual costs may be used in lieu of actual costs if approved by the SHA and the FHWA* Division Administrator. *These average rates should be*

adjusted at least once annually to take into account known anticipated changes and correction for any over or under applied costs for the preceding period.

(2) *When the utility is a self-insurer, there may be reimbursement at experience rates properly developed from actual costs. The rates cannot exceed the rates of a regular insurance company for the class of employment covered.*

d. *Overhead and Indirect Construction Costs*

(1) *Overhead and indirect construction costs not charged directly to work order or construction accounts may be allocated to the relocation provided the allocation is made on an equitable basis. All costs included in the allocation shall be eligible for Federal reimbursement, reasonable, and actually incurred by the utility.*

(2) *Costs not eligible for Federal reimbursement include, but are not limited to, the costs associated with advertising, sales promotion, interest on borrowings, the issuance of stock, bad debts, uncollectible accounts receivable, contributions, donations, entertainment, fines, penalties, lobbying, and research programs.*

(3) *The records supporting the entries for overhead and indirect construction costs shall show the total amount, rate, and allocation basis for each additive, and are subject to audit by representatives of the State and Federal Government.*

e. *Materials and Supply Costs*

(1) *Materials and supplies, if available, are to be furnished from company stock except that they may be obtained from other sources near the project site when available at a lower cost. When not available from company stock, they may be purchased either under competitive bids or existing continuing contracts under which the lowest available prices are developed. Minor quantities of materials and*

supplies and proprietary products routinely used in the utility's operation and essential for the maintenance of system compatibility may be excluded from these requirements. The utility shall not be required to change its existing standards for materials used in permanent changes to its facilities. Costs shall be determined as follows:

(a) Materials and supplies furnished from company stock shall be billed at the current stock prices for such new or used materials at time of issue.

(b) Materials and supplies not furnished from company stock shall be billed at actual costs to the utility delivered to the project site.

(c) A reasonable cost for plant inspection and testing may be included in the costs of materials and supplies when such expense has been incurred. The computation of actual costs of materials and supplies shall include the deduction of all offered discounts, rebates, and allowances.

(d) The cost of rehabilitating rather than replacing existing utility facilities to meet the requirements of a project is reimbursable, provided this cost does not exceed replacement costs.

(2) Materials recovered from temporary use and accepted for reuse by the utility shall be credited to the project at prices charged to the job, less a consideration for loss in service life at 10 percent. Materials recovered from the permanent facility of the utility that are accepted by the utility for return to stock shall be credited to the project at the current stock prices of such used materials. Materials recovered and not accepted for reuse by the utility, if determined to have a net sale value, shall be sold to the highest bidder by the HA or utility

following an opportunity for HA inspection and appropriate solicitation for bids. If the utility practices a system of periodic disposal by sale, credit to the project shall be at the going prices supported by records of the utility.

(3) *Federal participation may be approved for the total cost of removal when either such removal is required by the highway construction or the existing facilities cannot be abandoned in place for aesthetic or safety reasons. When the utility facilities can be abandoned in place but the utility or highway constructor elects to remove and recover the materials, Federal funds shall not participate in removal costs which exceed the value of the materials recovered.*

(4) *The actual and direct costs of handling and loading materials and supplies at company stores or materials yards, and of unloading and handling recovered materials accepted by the utility at its stores or material yards are reimbursable. In lieu of actual costs, average rates which are representative of actual costs may be used if approved by the SHA and the FHWA* Division Administrator. *These average rates should be adjusted at least once annually to take into account known anticipated changes and correction for any over or under applied costs for the preceding period. At the option of the utility, 5 percent of the amounts billed for the materials and supplies issued from company stores and material yards or the value of recovered materials will be reimbursed in lieu of actual or average costs for handling.*

f. *Equipment Costs. The average or actual costs of operation, minor maintenance, and depreciation of utility-owned equipment may be reimbursed. Reimbursement for utility-owned vehicles may be made at average or actual costs. When utility-owned equipment is not available, reimbursement will be limited to the amount of rental paid (1) to the lowest qualified bidder, (2) under existing continuing contracts at reasonable costs, or (3) as an exception by negotiation when (1) and (2) are impractical due to project location or schedule.*

g. Transportation Costs

(1) The utility's cost, consistent with its overall policy, of necessary employee transportation and subsistence directly attributable to the project is reimbursable.

(2) Reasonable cost for the movement of materials, supplies, and equipment to the project and necessary return to storage including the associated cost of loading and unloading equipment is reimbursable.

h. Credits

(1) Credit to the highway project will be required for the cost of any betterments to the facility being replaced or adjusted, and for the salvage value of the materials removed.

(2) Credit to the highway project will be required for the accrued depreciation of a utility facility being replaced, such as a building, pumping station, filtration plant, power plant, substation, or any other similar operational unit. Such accrued depreciation is that amount based on the ratio between the period of actual length of service and total life expectancy applied to the original cost. Credit for accrued depreciation shall not be required for a segment of the utility's service, distribution, or transmission lines.

(3) No betterment credit is required for additions or improvements which are:

(a) required by the highway project,

(b) replacement devices or materials that are of equivalent standards although not identical,

(c) replacement of devices or materials no longer regularly manufactured with next highest grade or size,

(d) required by law under governmental and appropriate regulatory commission code, or

(e) required by current design practices regularly followed by the company in its own work, and there is a direct benefit to the highway project.

(4) When the facilities, including equipment and operating facilities, described in paragraph 10(h)(2) are not being replaced, but are being rehabilitated and/or moved, as necessitated by the highway project, no credit for accrued depreciation is needed.

(5) In no event will the total of all credits required under the provisions of this directive exceed the total costs of adjustment exclusive of the cost of additions or improvements necessitated by the highway construction.

i. Billings

(1) After the executed HA/utility agreement has been approved by the FHWA Division Administrator, *the utility may be reimbursed through the SHA by progress billings for costs incurred. Cost for materials stockpiled at the project site or specifically purchased and delivered to the utility for use on the project may also be reimbursed on progress billings following approval of the executed HA/utility agreement.*

(2) The utility shall provide one final and complete billing of all costs incurred, or of the agreed-to lump-sum, at the earliest practicable date. The final billing to the FHWA shall include a certification by the SHA that the work is complete, acceptable, and in accordance with the terms of the agreement.

(3) All utility cost records and accounts relating to the project are subject to audit by representatives of the State and Federal Government for a period of 3 years from the date final payment has been received by the utility.

(4) Reimbursement for a final utility billing shall not be approved until the HA furnishes evidence that it has paid the utility from its own funds.

11. ALTERNATE PROCEDURE

a. *This alternate procedure is provided to simplify the processing of utility relocations or adjustments under the provisions of this directive. Under this procedure, except as otherwise provided in paragraph 11(b), the SHA is to act in the relative position of the FHWA* Division Administrator *for reviewing and approving the arrangements, fees, estimates, plans, agreements, and other related matters required by this directive as prerequisites for authorizing the utility to proceed with and complete the work.*

b. *The scope of the SHA's approval authority under the alternate procedure includes all actions necessary to advance and complete all types of utility work under the provisions of this directive except in the following instances:*

(1) *Utility relocations and adjustments involving major transfer, production, and storage facilities such as generating plants, power feed stations, pumping stations and reservoirs.*

(2) *Utility relocations falling within the scope of paragraphs 8(h), (i), and (j) and 5(i).*

c. *Each SHA is encouraged to adopt the alternate procedure and file a formal application for approval by the FHWA* Regional Administrator. *The application must include the following:*

(1) *The SHA's written policies and procedures for administering and processing Federal-aid utility adjustments. Those policies and procedures must make adequate provisions with respect to the following:*

(a) *Compliance with the requirements of this directive, except as otherwise provided by paragraph 11b and the provisions of FHPM 6-6-3-2, Accommodation of Utilities.*

(b) *Advance utility liaison, planning, and coordination measures for providing adequate lead time and early scheduling of utility relocation to minimize interference with the planned highway construction.*

(c) *Appropriate administrative, legal, and engineering review and coordination procedures as needed to establish the legal basis of the HA's payment; the extent of eligibility of the work under State and Federal laws and regulations; the more restrictive payment standards under paragraph 3(d); the necessity of the proposed utility work and its compatibility with proposed highway improvements; and the uniform treatment of all utility matters and actions, consistent with sound management practices.*

(d) *Documentation of actions taken in compliance with the SHA policies and the provisions of this directive, shall be retained by the SHA.*

(2) *A statement signed by the chief administrative officer of the SHA certifying that:*

(a) *Federal-aid utility relocations will be processed in accordance with the applicable provisions of this directive, and the SHA's utility policies and procedures submitted under paragraph 11(c)(1).*

(b) *Reimbursement will be requested only for those costs properly attributable to the proposed highway construction and eligible for participation under the provisions of this directive.*

d. *The SHA's application and any changes to it will be submitted to the FHWA for review and approval* by the FHWA Regional Administrator.

e. *After the alternate procedure has been approved, the FHWA* Division Administrator *may authorize the SHA to proceed with utility relocation on a project in accordance with the certification, subject to the following conditions:*

(1) *The utility work must be included in an approved program.*

(2) *The SHA must submit a request in writing for such authorization. The request shall include a list of the utility relocations to be processed under the alternate procedure, along with the best available estimate of the total costs involved.*

f. *The FHWA* Regional Administrator *may suspend approval of the alternate procedure when any FHWA review discloses noncompliance with the certification. Federal funds will not participate in relocation costs incurred that do not comply with the requirements under paragraph 11(c)(1).* [*OMB Control Number 2125-0533*]