REPORT OF COMMITTEE ON HIGHWAY LIGHTING

BURTON W. MARSH, *Chairman*

ESTIMATING COSTS OF FIXED ILLUMINATION FOR DEPRESSED URBAN FREEWAYS

SYNOPSIS

This report presents a basis for estimating costs of fixed illumination for depressed urban freeways. The cost estimates given in Tables 1 to 4 represent the combined judgment of two large equipment manufacturers and are based on four comparable projects in different parts of the country. Tables 6 to 8 give cost data from the experience of the New Jersey State Highway Department. Four methods of financing are discussed.

Although the report does not define or recommend any standards it is necessary to make some assumptions as a basis for estimating. The more important assumptions are. *Cross sections*, two 24-ft. and two 36-ft pavements with 10-ft. divider, *ramps* 20-ft roadways, *poles and wiring*, at sides of freeway, metal poles and underground wires, also wood poles and overhead wires; *illumination intensities*, 0 8 foot-candles and (New Jersey) 0.45 foot-candles, *lamps*, filament, sodium and mercury, *luminaires*, reflector-refractor, reflector-deflector, reflector and refractor types, 25 and 30 ft. mounting heights, staggered arrangement; *bracket lengths*, 12 ft and (New Jersey) 16 ft.; *circuits*, series, with insulating transformer at each lamp; *prices* based on pre-war level.

Example: two 24-ft pavements, divided, 0 8 foot-candle illumination; metal poles and underground cable; 10,000-lumen filament lamps for freeway, 10,000-lumen mercury vapor lamps for ramps, six overhead bridges per mile, electricity at 1½ cents per kw-hr. Equipment purchased and installed by highway authority, electric energy and maintenance by contract with utility company For this case the total installed cost per mile is estimated to be $14,569 and annual operating cost per mile $3,083. These figures are based on equipment costs presented in tables, but maintenance costs were arbitrarily assumed to be 40% above those in tables

A considerable number of urban freeways are now being planned—and more will be. Stimulation is being given to the construction of such urban expressways by the Federal-Aid Highway Act of 1944 which provides substantial federal-aid funds for use in cities for each of the three fiscal years beginning July 1, 1946 Emphasis on urban highway needs also results from realization that the greatest deficiencies in highway facilities are in urban areas.

Among the many problems encountered in planning urban freeways, is highway lighting. Engineers working on such projects have sought data on which to base estimates of lighting costs.

To help meet this need this report has been prepared. The rough estimates presented, have been compiled in consultation with Federal, State and municipal engineers, electrical equipment manufacturers, and utility company representatives.

At the outset it should be emphasized that this report is not intended to define or recommend any standards whatever, either for highways or for highway lighting It has been necessary to base estimates on various assumptions as to freeway and ramp design and as to illumination intensities or levels and lighting systems. These assumptions are all clearly set forth. Engineers of the Public Roads Administration consider the assumed freeway design features reasonable as a basis for the cost estimates presented Where it is deemed desirable, sources of other assumptions are indicated. It is believed that highway engineers will be able to utilize the data presented, making necessary adaptations to fit cost levels and other variances applying to each specific project, in preparing approximate cost estimates

It should be pointed out that lighting requirements for an urban freeway may be different from those for an urban artery at grade. On the one hand, there are no pedestrians or grade intersections on the freeway. On the other hand, speeds will be higher on the freeway and there are the ramps and median strips to consider. Study of more data relating to accidents, speeds, driver behavior and driving comfort on well-lighted urban freeways will increase knowledge of the effects of lighting and will help indicate what illumination intensities or levels and other lighting characteristics should be. The Committee desires to obtain such data as rapidly as it can be made available.

Assumptions

This report is based on the following assumptions:

1 *Freeway Type* The freeway is depressed and in an urban area. Such a freeway is assumed to be reasonably close to the source of electric energy One of the reasons for the rather high operating costs in the New Jersey tables is that a considerable proportion of their illuminated highway mileage is not close to a power source Cost of producing electric energy is also higher in New Jersey than in areas, for example, where hydro-electric plants are the source.

2 *Cross-Section.* Two depressed freeway cross-sections are treated, as indicated in Figures 1 and 2 Freeway Design No 1 consists of two 24-ft pavements separated by a 10-ft. median strip. Freeway Design No. 2 consists of two 36-ft. pavements separated by a 10-ft median strip.

3 *Ramps* As indicated in Figure 3, ramps are assumed to have 20-ft roadways

4 *Service Roads.* Lighting of service or frontage roads is considered a separate project, and costs thereof are not included in the following freeway lighting estimates

5 *Time of Installation* Lighting facilities are installed as the freeway is constructed

6. *Bridges.* Since there will be much variance in the number of bridges over an urban freeway per mile, costs for additional facilities for under-bridge illumination are not included in the tables which follow. However, later a suggestion is included for a simple method of roughly approximating such extra under-bridge lighting costs.

7 *Cost Unit.* All costs are per mile of freeway or ramp.

8 *Poles* Lighting poles are located at the sides of the freeway, not in the median strip. It is believed that highway engineers will generally prefer the side locations and for the freeway cross-sections involved, there are lighting advantages.

9. *Intensities or Levels of Illumination.* Expert opinions differ considerably as to what the average level of illumination should be on a horizontal plane at roadway level. Our committee member who is in charge of highway lighting in New Jersey believes that 0.45 foot-candles is adequate where there are no pedestrians or grade crossings, and with pavement of reasonably high reflectivity (not black-top or black tinted concrete), and the New Jersey tables presented herein are on that basis. Other members and the Illuminating Engineering Society's Committee on Street and Highway Lighting believe that the desirable minimum level of illumination is 0 8 foot-candles for an artery carrying heavy vehicular traffic with little or no pedestrian traffic, and Tables 1 to 4 are on that basis [1] There had been some indication that California was considering a much higher illumination level, but its State highway engineer stated that California while not having adopted definite standards generally conforms to IES standards for lighting

10. *Illuminants,* In Tables 1 to 4 data are presented for filament lamps, and also for sodium and mercury lamps in the belief that information on these vapor sources is desired. The New Jersey data are for filament lamps.

11 *Luminaires,* Tables 1 to 4: The reflector-refractor type, provides medium beam spread, for 10,000-lumen filament lamps; the reflector-deflector type, provides wide beam spread for 15,000-lumen filament lamps and for 16,000 lumen mercury lamps and the reflector type, provides wide beam spread, for 10,000 lumen sodium lamps

Tables 5 to 7 (New Jersey data) are for 6,000- and 4,000-lumen refractor type filament lamps, beam spread not indicated, for the freeway and ramps respectively

12 *Mounting Height.* Tables 1 to 4: Mounting height is 30 ft for 15,000-lumen filament lamps and 25 ft for others, in ac-

[1] The Illuminating Engineering Society's new "Recommended Practice of Street and Highway Lighting" has been published in the magazine *Illuminating Engineering* Vol XLI, No. 2, February 1946, p. 105

TABLE 1
LUMINAIRE SPACINGS TO PRODUCE 0 8 FOOTCANDLES AVERAGE
Luminaire Spacings Shown as "S" in Figures 1, 2, and 3

Lamp		Beam Spread of Luminaire	Freeway Design No 1		Freeway Design No 2		Ramp	
Type	Lumens		Spacing	No per Mile	Spacing	No per Mile	Spacing	No per Mile
			ft		ft		ft	
Filament	10,000	Medium	100[a]	54	75[a]	72	125–170	33
Filament	15,000	Wide	110[a]	48	85[a]	62	Not rec	
Sodium	10,000	Wide	70	75	50	108	125–165	34
Mercury	10,000	Medium	Not rec		Not rec		125–160	35
Mercury	16,000	Wide	100	53	75	70	Not rec	

NOTE The above luminaire spacings on the freeways are measured along the centerline of the divided roadway Spacings along each half of the divided roadway are twice the above values

[a] The small differences in spacing between the 10,000- and 15,000-lumen lamps are largely because of the difference in the beam spreads

TABLE 2
0 8 FOOTCANDLES
ESTIMATED INSTALLED COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 1 (FOUR LANES DIVIDED)

	Metal Poles, Underground Cable				Wood Poles, Overhead Wire			
Lamp and Luminaire Used								
Lamp Type	Fil	Fil	Sod	Mer	Fil	Fil	Sod	Mer
Lamp Lumens	10,000	15,000	10,000	16,000	10,000	15,000	10,000	16,000
No of Lamps	54	48	75	53	54	48	75	53
Luminaire Beam	Medium	Wide	Wide	Wide	Medium	Wide	Wide	Wide
Equipment Cost								
Luminaires	$1,000	$1,650	$4,700	$960	$1,000	$1,650	$4,700	$960
Lamps	50	90	540	350	50	90	540	350
Poles & Brackets	4,300	3,800	6,000	4,200	1,900	1,700	2,600	1,900
Insulating Transformers	950	1,300	[a]	1,000	950	1,300	[a]	1,000
Cable & Wire	1,000	1,000	1,100	1,000	400	400	400	400
Total Equipment	7,300	7,800	12,300	7,500	4,300	5,100	8,200	4,600
Cost of Installing (1939 Prices)	3,300	3,000	3,800	3,300	2,600	2,600	3,400	2,600
Total Installed Cost Approximately	$10,600	$10,800	$16,100	$10,800	$6,900	$7,700	$11,600	$7,200

[a] Insulating transformer is a part of the Sodium-vapor luminaire

ESTIMATED ANNUAL OPERATING COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 1

Lamp Watts and Life								
Watts per lamp	485	715	180	400	485	715	180	400
Watts per lamp including Insulating Transformers	540	755	220	435	540	755	220	435
Average service—operating Life, Hours	1,600	1,600	2,500	4,000	1,600	1,600	2,500	4,000
Maintenance Costs								
Lamp renewals, washing, patrolling, globe replacements, and minor repairs	$430	$480	$1,270	$580	$430	$480	$1,270	$580
Energy Costs								
Watts per lamp plus 10% line loss × 4000 hours per year								
@ 1¢ per Kwhr	1,280	1,590	730	1,010	1,280	1,590	730	1,010
@ 1½¢ per Kwhr	1,920	2,390	1,090	1,520	1,920	2,390	1,090	1,520
@ 2¢ per Kwhr	2,560	3,190	1,450	2,030	2,560	3,190	1,450	2,030
Approximate Total Annual Operating Cost								
@ 1¢ per Kwhr	1,710	2,070	2,000	1,590	1,710	2,070	2,000	1,590
@ 1½¢ per Kwhr	2,350	2,870	2,360	2,100	2,350	2,870	2,360	2,100
@ 2¢ per Kwhr	2,990	3,670	2,720	2,610	2,990	3,670	2,720	2,610

cordance with Illuminating Engineering Society's recommendations. Tables 5 to 8: mounting height is 25 ft.

13. *Luminaire Arrangement.* Luminaires are staggered, with luminaires along outside edges of roadways as in Figures 1 and 2. With this arrangement, each luminaire helps to build up the illumination on the far roadway midway between lamps on the far side.

Note: New Jersey data are based on the luminaire being above a position 2 ft. onto the second lane from the right pavement edge. To this extent Figures 1 and 2 are incorrect for New Jersey data

14. *Spacing.* Tables 1 and 5 give spacing required for each different lamp to provide the indicated average illumination level. Spacing depends not only on lamp lumens but also on the light distribution produced by the luminaire See Figures 1 and 2 on which it is indicated that the spacing figures (S) given in Tables 1 and 5 are the distances between points on the center line of the freeway to which luminaire positions on whichever side, are projected. The distance between two luminaires on the same side is therefore twice the spacing figure given.

15. *Pole Location* Tables 1 to 4: Where provision is made for a shoulder, poles are 8 ft. from outer edge of pavement, thus leaving about a 7-ft. clear shoulder width, since the base of the pole is about 2 ft in diameter If

TABLE 3

0 8 FOOTCANDLES

ESTIMATED INSTALLED COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 2 (SIX LANES DIVIDED)

	Metal Poles, Underground Cable				Wood Poles, Overhead Wire			
Lamp and Luminaire Used								
Lamp Type	Fil	Fil.	Sod	Mer	Fil	Fil	Sod	Mer
Lamp Lumens	10,000	15,000	10,000	16,000	10,000	15,000	10,000	16,000
No of Lamps	72	62	108	70	72	62	108	70
Luminaire Beam	Medium	Wide	Wide	Wide	Medium	Wide	Wide	Wide
Equipment Cost								
Luminaires	$1,300	$2,100	$6,800	$1,300	$1,300	$2,100	$6,800	$1,300
Lamps	90	120	780	470	90	120	780	470
Poles & Brackets	5,800	5,000	8,600	5,600	2,500	2,200	3,800	2,400
Insulating Transformers	1,200	1,600	[a]	1,300	1,200	1,600	[a]	1,300
Cable & Wire	1,100	1,000	1,200	1,100	400	400	400	400
Total Equipment	9,500	9,800	17,400	9,800	5,500	6,400	11,800	5,900
Cost of Installing (1939 Prices)	3,800	3,500	4,900	3,700	3,200	2,900	4,200	3,100
Total Installed Cost Approximately	$13,300	$13,300	$22,300	$13,500	$8,700	$9,300	$16,000	$9,000

[a] Insulating transformer is a part of the Sodium-vapor luminaire

ESTIMATED ANNUAL OPERATING COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 2

Lamp Watts and Life								
Watts per lamp	485	715	180	400	485	715	180	400
Watts per lamp including Insulating Transformers	540	755	220	435	540	755	220	435
Average Service Life, Hours	1,600	1,600	2,500	4,000	1,600	1,600	2,500	4,000
Maintenance Costs								
Lamp renewals, washing, patrolling, globe replacements, and minor repairs	$580	$620	$1,840	$770	$580	$620	$1,840	$770
Energy Costs								
Watts per lamp plus 10% line loss × 4000 hours per year								
@ 1¢ per Kwhr	1,710	2,060	1,050	1,340	1,710	2,060	1,050	1,340
@ 1½¢ per Kwhr	2,570	3,090	1,570	2,010	2,570	3,090	1,570	2,010
@ 2¢ per Kwhr	3,420	4,120	2,090	2,680	3,420	4,120	2,090	2,680
Approximate Total Annual Operating Cost								
@ 1¢ per Kwhr	2,290	2,680	2,890	2,110	2,290	2,680	2,890	2,110
@ 1½¢ per Kwhr	3,150	3,710	3,410	2,780	3,150	3,710	3,410	2,780
@ 2½¢ per Kwhr	4,000	4,740	3,930	3,450	4,000	4,740	3,930	3,450

conditions require the side slope to begin closer to the edge of the pavement, the 8-ft. distance may be deemed unnecessary, the bracket arm length reduced and shorter poles used, with some slight cost reductions.

Studies on the Outer Drive in Chicago indicated that where cars went over a curb and off the express roadway they almost always came to rest within 8 ft. laterally from the face of the curb. About 90 per cent of the cars

TABLE 4
0.8 FOOTCANDLES
ESTIMATED INSTALLED COST OF LIGHTING PER MILE OF RAMP

	Metal Poles, Underground Cable			Wood Poles, Overhead Wire		
Lamp and Luminaire Used						
Lamp Type	Fil	Sodium	Mercury	Fil	Sodium	Mercury
Lamp Lumens	10,000	10,000	10,000	10,000	10,000	10,000
No of Lamps	33	34	35	33	34	35
Luminaire Beam	Narrow	Medium	Medium	Narrow	Medium	Medium
Equipment Cost						
Luminaires	600	2,100	650	600	2,100	650
Lamps	30	350	260	30	350	260
Poles & Brackets	2,600	2,700	2,800	1,200	1,200	1,200
Insulating Transformers	600	[a]	650	600	[a]	650
Cable & Wire	1,000	950	900	350	350	350
Total Equipment	4,800	6,100	5,300	2,800	4,000	3,100
Cost of Installing (1939 Prices)	2,600	2,700	2,700	2,000	2,100	2,100
Total Installed Cost Approximately	$7,400	$8,800	$8,000	$4,800	$6,100	$5,200

[a] Insulating transformer is a part of the Sodium-vapor luminaire

ESTIMATED ANNUAL OPERATING COST OF LIGHTING PER MILE OF RAMP

Lamp Watts and Life						
Watts per lamp	485	180	250	485	180	250
Watts per lamp including Insulating Transformers	540	220	278	540	220	278
Average Service Life, Hours	1,600	2,500	2,500	1,600	2,500	2,500
Maintenance Costs						
Lamp renewals, washing, patrolling, globe replacements and minor repairs	$260	$580	$560	$260	$580	$560
Energy Costs						
Watts per lamp plus 10% line loss × 4000 hours per year						
@ 1¢ per Kwhr	780	330	430	780	330	430
@ 1½¢ per Kwhr	1,180	490	640	1,180	490	640
@ 2¢ per Kwhr	1,570	660	860	1,570	660	860
Approximate Total Annual Operating Cost						
@ 1¢ per Kwhr	1,040	910	990	1,040	910	990
@ 1½¢ per Kwhr	1,440	1,070	1,200	1,440	1,070	1,200
@ 2¢ per Kwhr	1,830	1,240	1,420	1,830	1,240	1,420

TABLE 5
NEW JERSEY LUMINAIRE SPACINGS TO PRODUCE 0.45 FOOTCANDLES AVERAGE
(Luminaire Spacings Shown as "S" in Figures 1, 2 and 3

Lamp		Freeway Design No 1		Freeway Design No. 2		Ramp	
Type	Lumens	Spacing	No per Mile	Spacing	No per Mile	Spacing	No. per Mile
		ft		*ft*		*ft*	
Filament	6,000	150	35	120	44		
Filament	4,000					150 (approx.)	35

Note The above luminaire spacings on the freeways are measured along the centerline of the divided roadways. Spacings along each half of the divided roadway are twice the above values No information was submitted on the beam spread of the Luminaire used came to rest within 6 ft. of the face of the curb.

The New Jersey tables (5 to 8) are based on poles 2 ft. back from the curb.

16. *Bracket Length.* Tables 1 to 4: Brackets are 12 ft. long, thus placing the luminaire 4 ft out onto the outside lane. A committee member representing one of the largest electrical equipment manufacturers stated that 4 to 6 ft. out over the outside lane was the desirable location for re-directive luminaires.

Tables 5 to 7. New Jersey, as stated above, favors the luminaire being located 2 ft. onto the second lane from the right pavement edge; hence Tables 5 to 7 are based on a 16 foot bracket.

17. *Type of Pole and Wiring.* Estimates are submitted for metal poles and underground cable, and also for wood poles and overhead cable. The former will generally be considered more in keeping with desirable aesthetic standards for such freeways.

Tables 1 to 4 are based on rubber covered, non-armored, direct burial cable. Duct is provided only at cross-overs, bridges, etc. where protection of cable is needed. In other locations the less costly direct burial cable and

TABLE 6

NEW JERSEY (0.45 FOOTCANDLES)
ESTIMATED INSTALLED COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 1
(FOUR LANES DIVIDED)

	Metal Poles and Underground Cable	Wood Poles, Overhead Wire
Lamp and Luminaire Used		
Lamp Type	Filament	Filament
Lamp Lumens	6,000	6,000
Number of Lamps	35	35
Luminaire Beam	(information	not available)
Equipment Cost		
Luminaires	$875	$875
Lamps	36	36
Poles & Brackets	2,975	963
Insulating Transformers	910	910
Cable & Wire	1,270	294
Total Equipment	6,066	3,078
Cost of Installing	3,412	2,173
Total Estimated Installed Cost	$9,478	$5,251

ESTIMATED ANNUAL OPERATING COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 1

Lamp Watts and Life	(information not available, costs included in following items)	
Special Maintenance Costs (Ordinary maintenance including lamp renewals, washing, patrolling, globe replacements, and minor repairs is covered by *utility rate* shown under Energy Costs below) Other maintenance including painting standards, etc	$350	$350
Energy Costs *Utility rate* in addition to energy charge includes ordinary maintenance at total cost of $45 per lamp per year	1,575	1,575
Estimated Total Annual Operating Costs	$1,925	$1,925

TABLE 7

NEW JERSEY (0 45 FOOTCANDLES)
ESTIMATED INSTALLED COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 2
(SIX LANES DIVIDED)

	Metal Poles and Underground Cable	Wood Poles, Overhead Wire
Lamp and Luminaire Used		
Lamp Type	Filament	Filament
Lamp Lumens	6,000	6,000
Number of Lamps	44	44
Luminaire Beam	(information	not available)
Equipment Cost		
Luminaires	$1,100	$1,100
Lamps	45	45
Poles & Brackets	3,740	1,210
Insulating Transformers	1,144	1,144
Cable & Wire	1,313	310
Total Equipment	$7,342	$3,809
Cost of Installing	3,828	2,791
Total Estimated Installed Cost	$11,170	$6,600

ESTIMATED ANNUAL OPERATING COST OF LIGHTING PER MILE OF FREEWAY—DESIGN NO 2

Lamp Watts and Life	(information not available; costs included in following items)	
Special Maintenance Costs (Ordinary maintenance including lamp renewals, washing, patrolling, globe replacements, and minor repairs, is covered by *utility rate* shown under Energy Costs below) Other maintenance including painting standards, etc	$440	$440
Energy Costs *Utility rate* in addition to energy charges includes ordinary maintenance at total cost of $45 per lamp per year	1,980	1,980
Estimated Total Annual Operating Costs	$2,420	$2,420

the rubber covering are deemed satisfactory. There should be few occasions when there would be danger of someone digging into them Some engineers may prefer armored, direct burial cable and some may prefer ducts In such cases appropriate additions should be

TABLE 8
NEW JERSEY (0 45 FOOTCANDLES)
ESTIMATED INSTALLED COST OF LIGHTING PER MILE OF RAMP
(Metal Poles and Underground Cable No information available on use of Wood Poles with Overhead Wires)

Lamp and Luminaire Used	
Lamp Type	Filament
Lamp Lumens	4,000
Number of Lamps	35
Luminaire Beam	(information not available)
Equipment Cost	
Luminaires	$875
Lamps	26
Poles & Brackets	2,625
Insulating Transformers	910
Cable & Wire	923
Total Equipment Cost	$5,359
Cost of Installing	3,412
Total Estimated Installed Cost	$8,771

ESTIMATED ANNUAL OPERATING COST OF LIGHTING PER MILE OF RAMP

Lamp Watts and Life	(information not available, costs included in following items)
Special Maintenance Costs	
(Ordinary maintenance including lamp renewals, washing, patrolling, globe replacements, and minor repairs is covered by *utility rate* shown under Energy Costs below)	
Other maintenance including painting standards, etc	$350
Energy Costs	
Utility rate in addition to energy charges includes ordinary maintenance at total cost of $35 per lamp per year	1,225
Estimated Total Annual Operating Costs	$1,575

made to cost estimates presented in Tables 1 to 4

Tables 5 to 8 (New Jersey) are based on No 8 parkway cable (an armored cable).

18 *Circuits* Tables 1 to 4 and 5 to 7 are based on series circuits, with an insulating transformer at each lamp In general, opinion is that insulating transformers are worth the additional costs involved, for added safety and other protective benefits. However, there are some who may hold that they are not worth the costs involved. If insulating transformers are omitted, the savings would be about $20 per transformer (one at each pole) plus about $15 because a pole could be used which did not contain a place to house the transformer. Against this approximately $35 saving, there would be an offsetting higher cost of cable then required, so the net saving might be about $30 per pole

Circuit costs in this report do not include constant current regulators and control equipment which are assumed to be provided by the utility Should a State decide to buy only energy from a utility or should it decide to provide all equipment and provide energy itself, charges would have to be included for such items as indicated in this paragraph

Ramp Lighting Assumptions

1. *Ramp Illumination* Tables 1 and 4, 0.8 foot-candles average Tables 5 and 8, 0.45 foot-candles average. Traffic volumes and speeds are lower than on freeway but hazards are increased by curves, by converging and diverging flows, and often by hesitancy of those unfamiliar with the road plan or uncertain of place to leave freeway

2 *Ramp Illuminants.* Tables 1 and 4, filament, sodium and mercury vapor lamps.

3. *Ramp Luminaires.* Tables 1 and 4, reflector-refractor type, providing medium beam spread, for 10,000-lumen filament and 10,000-lumen mercury lamps. Tables 5 and 8: refractor type, 4000-lumen filament lamps.

4 *Ramp Mounting Height* Table 4, 25 ft ; Table 8, 25 ft.

5. *Ramp Arrangement* Lighting units are on one side only and along outer edges of ramps as they leave to enter the freeway, changing sides if need be to keep luminaires on the outsides of curves, where they are most effective

6 *Ramp Spacing* Tables 1 and 4, as shown in Table 1 and on Figure 3 Note that as curvature increases, spacing decreases.

New Jersey data, approximately 150 ft as shown in Table 5

7 *Ramp Pole Location, Bracket Length, Types of Poles and Wiring, and Circuits.* Tables 1 and 4, same assumptions as for freeways Table 8, poles—25-ft mounting height, 4-ft mast arms, positioned 2 ft back of curbing Other assumptions believed to be same as for freeway

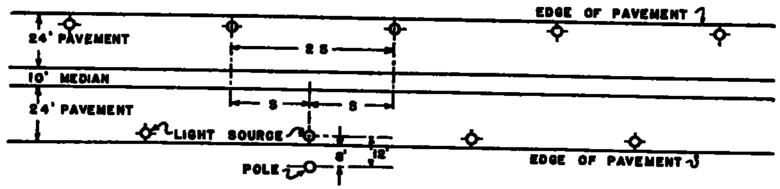

Figure 1. Freeway Design No. 1 Showing lighting layout for which cost estimates are provided. Lamp spacing (S) is shown in Table 1 for different lamp sizes and luminaires.

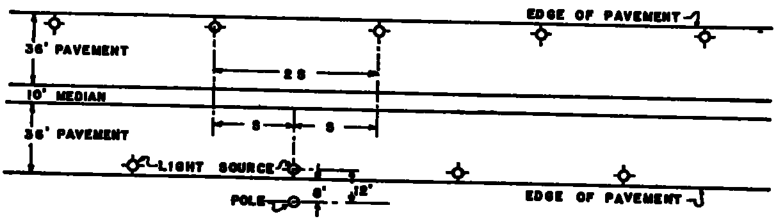

Figure 2. Freeway Design No. 2 Showing lighting layout for which cost estimates are provided. Lamp spacing (S) is shown in Table 1 for different lamp sizes and luminaires.

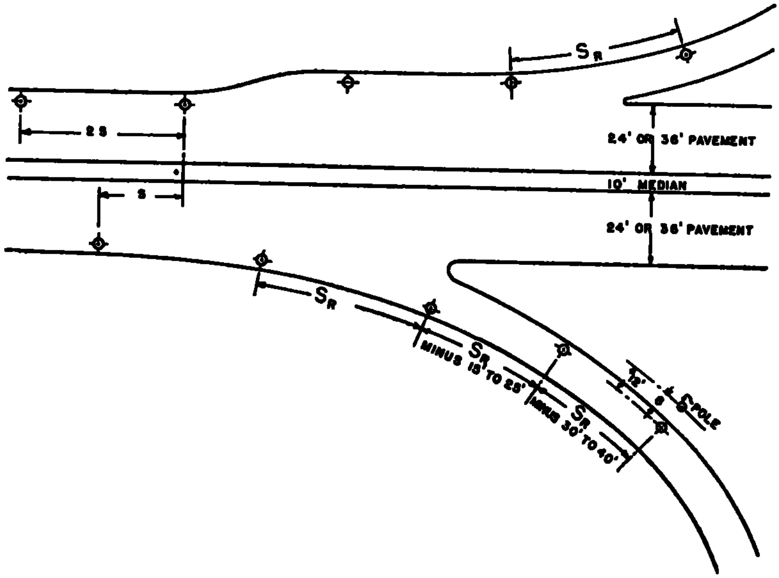

Figure 3. Plan of Ramps with Typical Lighting Layouts Leaving and Entering the Freeway and on Curves.

Methods of Financing

There are four principal methods of financing roadway lighting costs, as follows:

1 The public authority may contract with the local utility to make the entire original investment, maintain, repair and as needed renew the equipment and provide the energy. For this service the utility usually makes a flat charge of so much per lighting unit per year and all costs and profit are reflected in that charge.

2. The public authority may make the original investment, and contract with the utility for maintenance and energy. Under this plan the utility usually provides constant-current regulators and control equipment. Maintenance contracts generally cover lamp washing and renewals, patrolling, globe replacements and minor repairs. Major repairs, painting of poles and cable replacement are generally the responsibility of the public authority.

3. The public authority may make the original investment, and provide own maintenance, and contract with the utility only for energy

4. The public authority may make the original investment, and provide maintenance and energy.

Most highway authorities, it is believed, will not favor method No 1 because of desire to keep at a minimum their mounting annual costs for maintenance and other annual costs of a similar nature which reduce funds available for construction. *It is believed that in general highway authorities will prefer to make the sort of original capital investment involved in method No. 2 and the cost data presented are based on this method of financing.* Should the highway authority favor method No. 1, it should go to the utility company with specifications for the lighting system desired and negotiate an annual cost contract. In doing so, it should be realized that utility companies generally pay considerably higher interest rates than a public authority, and of course overhead and profit items will also be involved.

Method No. 3 and No. 4 would require that the highway authority purchase tower truck equipment and necessary accessories and set up a maintenance and patrol staff and office with garage and service shop. The utility company in cities already has such equipment and usually is doing such work on other street lighting in the vicinity. Hence, it should be possible to make a suitable maintenance contract which would be more economical to the highway authority than for the public authority to undertake such maintenance. If, however, a highway authority decides to do its own maintenance, the cost data submitted must be supplemented by costs for the several additional items stated in this paragraph.

Method No. 4 would also require provision of a plant for generating electric energy and provision of power lines and all necessary accessories to deliver the desired electric energy to the freeway. Unless the utility company proposal is very high, it is not likely that this method would be considered by the highway authority for a small mileage of urban freeways.

Amortization

In methods No. 2, 3 and 4, an annual amortization charge will not usually be carried on the public authority's books. Therefore, no amortization figure has been included in the tables presented, but it is part of the true cost of a lighting system.

In any comparison between a proposal of an utility company for financing by method No. 1 with installed costs of the other methods of financing, the public authority must in fairness consider an equitable amortization figure. The highway authority should satisfy itself that the basis of amortization is appropriate. This requires obtaining data on life expectancy of each of the constituent parts of the system and using a weighted average as a basis for deciding upon a reasonable weighted amortization period and hence a fair annual amortization figure. In comparing true costs between methods 2, 3 and 4, proper consideration should also be given to amortization.

It should be emphasized that in addition to the costs presented in the tables the public authority must pay costs for major repairs, replacement of cables and for such replacement of poles as are not paid for by parties breaking them, as these replacements and major repairs become necessary. It should also be noted that the New Jersey data include items for certain maintenance including painting poles, which are not paralleled in Tables 1 to 4.

Operating Costs

There are differences in the items included in "operating cost" in different places. Thus as stated immediately above, the New Jersey data differ from the data in Tables 1 to 4. Therefore, before using tables of rough operating cost, the highway engineer should check with his utility company to appraise the suitability of the estimating data presented herein

Variances in what is and is not included in "maintenance costs" are also likely to be encountered. Hence, the highway engineer will wish to examine the detailed statement of what the utility company proposes to include under that term, and to work out such modifications as are deemed appropriate. For example just what are the limits of "minor repairs" (see Tables 2, 3 and 4 under "Maintenance Costs")?

Generally, the utility company will propose a figure per luminaire per year to cover lamp renewals, washing, patrolling for outages, globe replacements, minor repairs and electric energy. The data in Tables 2 to 4 are somewhat broken down to aid the engineer in appraising the annual figure proposed by the utility.

The maintenance computations presented assume group replacement of filament, sodium, and mercury lamps at approximately 80 per cent of the rated life in each case Such group replacement assures that the lamps will always be in good condition, and it minimizes outages with the attendant special trips by the service truck to make individual replacements. Further field experience with sodium and mercury lamps may show that in some cases the best overall balance between benefits and replacement costs may be obtained with group replacement intervals somewhat longer than 80 per cent of rated life.

Color of Light

Three illuminants are listed in Tables 1 to 4—filament, sodium vapor and mercury vapor. Each has advocates These tables will permit comparative cost analysis and thus help the engineer in his selection of illuminant.

Extensive researches comparing roadway lighting from filament, sodium and mercury sources have shown that for equal amounts of light equally distributed, there are no significant differences in visibility.

Yellow light in traffic signal practice means CAUTION. Hence, some traffic and highways engineers believe that it would be desirable to use sodium lighting with its distinctive yellow color, solely for identifying and illuminating hazardous locations This idea has been put into effect in some places. Were it to become a rather general practice, the meaning could probably be "sold" to the public. As a general highway illuminant, sodium is a high efficiency source and as will be seen in Tables 2 and 3, energy costs are much lower than for other illuminants. However, this advantage is more than offset by high maintenance costs. Human complexions have an unnatural appearance under sodium lighting, but objections on this basis would presumably be much less severe than where pedestrians are involved.

Mercury lighting is of a color which brings out the greens in lawn and foliage. It is a high efficiency light but it also gives human complexions an unnatural appearance.

A differential in color of light between a freeway and its ramps may be found of assistance to traffic movement Thus, if filament lighting were used on the freeway, and sodium or mercury lighting on ramps, the driver speeding along and desiring to remain on the freeway would always follow the filament lighting, while the color change would presumably be helpful to a driver looking ahead to spot a ramp location.

Sources of Cost Data

Tables 1 to 4 represent the combined judgment of representatives of two leading electric equipment manufacturers. Installed costs presented in Tables 2 to 4 are based on four representative comparable projects in different parts of the country. While there were appreciable variances in individual items, the variance between total installed costs per mile between the four projects was not over 20 per cent.

Annual operating cost data in Tables 2 to 4 are based on data accumulated by the representatives of the manufacturers from projects with which they were familiar.

Tables 6 to 8 present cost data from the experience of the New Jersey State Highway Department which has about 500 miles of lighted highways, not all of which however are at the illumination level of 0.45 footcandles for which those tables were prepared.

Price Levels

In using the installed cost data submitted, adjustment must be made for the difference in price levels between the time estimates are made and the levels which were in effect when the projects were undertaken which govern installed costs given in the tables.

Note that in Tables 2 to 4 installed costs are at 1939 prices.

In Tables 6 to 8, installed costs are also based on pre-war prices.

Tables

The same pattern is followed for Tables 1 to 4 and for Tables 5 to 8. First, there are presented descriptions of luminaires and spacings. Then follow cost data for both metal poles and underground wiring, and for wooden poles and overhead wiring for each of the two freeway cross-sections or "designs" and then for ramps.

In each case estimated installed costs are presented, followed by estimated annual operating costs. In Tables 2 to 4 operating costs are presented for three energy costs: one cent, one and one-half cents and two cents per kilowatt-hour.

Estimating Cost of Installed Under-Bridge Lighting

For estimating purposes, assume that two extra lighting units similar to others along the freeway will be installed near each bridge. A lower mounting height will generally be necessary. This will decrease pole cost somewhat. The light distribution and illumination level will also be affected.

Examination of items in Tables 2 and 3 and in Tables 6 and 7 will show that installed costs will be increased by approximately the added number of luminaires per mile—the two exceptions being for shorter poles for under-bridge lighting and a considerably less than proportionate increase in the item "Cable and Wire" These differences will not be large however, and are on the conservative side in that the proposed procedure will produce larger cost figures than would more precise analysis.

Therefore count the number of bridges per mile over the freeway, assume two additional complete sets of lighting equipment for each bridge. Increase the "Total Equipment" cost estimate by the ratio of the new number of lamps (with two additional for each bridge) to the number of lamps without under-bridge lighting included. Increase the "Cost of Installing" by a suitable percentage to take account of new price levels Then pro-rate this figure by the above ratio Add the two new cost figures to get the "Total Installed Cost" including under-bridge lighting

Annual operating cost estimates should be increased in a similar way.

Example of Use of Data

Assume that the freeway is approximately in accord with design No. 1, that there are six bridges per mile, that an illumination level of 0.8 foot-candles has been decided upon for both freeway and ramps. Assume that metal poles and underground cable have been decided upon for both freeway and ramps. Assume that 10,000-lumen filament luminaires of reflector-refractor type with medium beam spread have been selected for the freeway, while 10,000-lumen mercury vapor luminaires with medium beam spread have been selected for the ramps Assume that equipment costs are as given in Table 2, but that cost of installing and maintenance costs will be increased 40 per cent (note: no significance to this figure). Assume that electric energy costs 1½ cents per kilowatt hour Assume that financing method No. 2 is selected.

What will be the estimated costs per mile of freeway and per mile of ramp?

Tables 2 and 4 provide the basis for estimating these costs.

The following tabulation shows how the desired estimates are obtained and gives an idea of costs based on the foregoing assumptions:

1 *Estimated Installed Cost of Lighting per Mile of Freeway—Design No 1* (at 0 8 footcandles)	
Equipment Cost (including under-bridge lighting)	
66/54 × $7,300	$8,922
Cost of Installing (including under-bridge lighting)	
1 40 × $3,300 = $4,620	
66/54 × $4,620	$5,647
Total Installed Cost (per mile of freeway including under-bridge lighting)	$14,569
2 *Estimated Annual Operating Cost of Lighting per Mile of Freeway—Design No 1* (at 0 8 footcandles)	
Maintenance Costs (including under-bridge lighting)	
1 40 × $430 = $602	
66/54 × $602	$736
Energy Costs (including under-bridge lighting, at 1½¢ per kwhr)	
66/54 × $1,920	$2,347
Approximate Total Annual Operating Cost (per mile of freeway, including under-bridge lighting)	$3,083
3 *Estimated Installed Cost of Lighting per Mile of Ramp* (at 0 8 footcandles)	
Equipment Cost	$5,300
Cost of Installing	
1 40 × $2,700	$3,780
Total Installed Cost (per mile of ramp)	$9,080

4. *Estimated Annual Operating Cost of Lighting per Mile of Ramp* (at 0 8 footcandles)

Maintenance Costs	
1 40 × $580	$812
Energy Costs (at 1½¢ per kwhr)	$640
Approximate Total Annual Operating Cost (per mile of ramp)	$1,452

The two total figures per mile of freeway would be multiplied by the length of the freeway in miles to obtain the total costs for the freeway part of the project.

The two total figures per mile of ramp would be multiplied by the total length of ramps in miles to obtain the total costs for the ramp part of the project

Thus, on the basis of these assumptions and if there were one mile of freeway and one-half mile of ramps, the total estimated installed cost (for freeway and ramps) for such a project would be $19,109—($14,569 + ½ 9,080)—and the total estimated annual operating cost would be $3,809—($3,083 + ½ 1,452).

To the costs obtained add a suitable average annual cost for major repairs and replacements to make the estimate complete, assuming that financing method No 2 is used.