NATIONAL EVALUATION PROGRAM
PHASE I FINAL REPORT

Street Lighting Projects

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ABSTRACT

The purpose of this report is to detail the present state of knowledge regarding the impact of street lighting on crime and the fear of crime, based on a comparative analysis of past and on-going street lighting projects whose description and impact have either been documented or are easily accessible. As with every NEP Phase I study, this report does not purport to be prescriptive with respect to the design of street lighting projects. The report briefly traces the historical and technical development of street lighting; reviews the pertinent issues in street lighting and crime; develops an evaluation framework for the comparative analysis of street lighting projects; undertakes a systematic assessment of available evaluation studies in street lighting; outlines a single project evaluation design; and identifies gaps in the present knowledge base and makes recommendations concerning future research and evaluation activities which should be undertaken to fill those gaps.

Although the paucity of reliable and uniform data and the inadequacy of available evaluation studies preclude a definitive statement regarding the relationship between street lighting and crime, a number of policy-relevant findings are contained in the report. In particular, while there is *no* statistically significant evidence that street lighting impacts the level of crime, especially if crime displacement is taken into account, there is a *strong* indication that increased lighting--perhaps lighting uniformity--decreases the fear of crime. Consequently, it is recommended that LEAA *continue* to fund street lighting projects for the purpose of deterring crime, but that the funding be a joint inter-agency effort so that the *range* of street lighting objectives is taken into consideration in the development of such projects.

In terms of future activities, two research activities and one evaluation activity are recommended at this time; they deserve immediate attention, and should be carried on concurrently, in coordination with each other. The two research activities attempt to *understand* the relationship between light and crime on a microscopic and a macroscopic level, respectively, while the evaluation activity would *assure* the uniformity and comparability of future street lighting evaluations.

Finally, the report should be of interest to criminal justice administrators who are concerned with the funding of street lighting projects. The report can also serve as an invaluable reference for criminal justice planners and professionals who are engaged in the technical aspects of designing, installing and maintaining street lighting systems.

PREFACE

On April 23, 1976, Public Systems Evaluation, Inc. (PSE) was awarded a one-year, National Evaluation Program grant by the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, United States Department of Justice, to conduct a study entitled "Phase I Evaluation of Street Lighting Projects." The purpose of the study is to determine the present state of knowledge regarding the impact of street lighting on crime and the fear of crime. To this end, PSE has undertaken an encompassing literature survey, an extensive telephone survey, and a limited site survey. The results of PSE's survey and evaluation efforts are, for the most part, contained in three formal reports: a preliminary report, a Final Report, and a Summary Report. The preliminary report, entitled "Issues in Street Lighting and Crime," was published in July, 1976; it was based on work performed during the first three months of PSE's study. In terms of content, the results documented in the preliminary report have, of course, been updated, expanded, refined and included in the Final Report. And the Summary Report can be regarded as an abridged version of the Final Report.

During the course of this evaluation study many individuals have been contacted either by telephone, in person or through written correspondence; they have collectively contributed to the knowledge base that is reflected herein. Exhibit A.3 in Appendix A of the Final Report contains a list of those individuals whose contribution the authors would like to formally acknowledge.

The authors have also been assisted by Dr. Thomas A. Reppetto, Dr. Saul I. Gass and Mr. Goodall Shapiro, all of whom are consultants to Public Systems Evaluation, Inc. (PSE) and a part of the project team. Other members of the PSE project team include Dr. Richard C. Larson and Mr. Victor O. Li, who have provided technical assistance; and Ms. Ellen P. Keir, Miss Joan Kanavich and Ms. Connie Toth, who have provided editing and typing support.

Finally, the authors would like to acknowledge the guidance and support provided by both Ms. Jan J. Hulla, the government project monitor, and Dr. Richard M. Rau, a member of the street lighting project review committee.

Street lights can be like that famous stone that falls in the desert where there are no ears to hear. Does it make a noise? Without effective eyes to see, does a light cast light? Not for practical purposes.

Jane Jacobs, 1961

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1 INTRODUCTION

Is street lighting an effective approach in the reduction and deterrence of crime? In 1967, the President's Crime Commission stated that [A.2-98, p. 51]*:

> There is no conclusive evidence that improved lighting will have lasting or significant impact on crime rates, although there are strong intuitive reasons to believe that it will be helpful....Improved street lighting may reduce some types of crime in some areas....With information on past, present and projected crime rates, it may be possible to assess better the impact of lighting on crime.

The creation of the Law Enforcement Assistance Administration (LEAA) in the Omnibus Crime Control and Safe Street Act of 1968 has accelerated the development and testing of anti-crime strategies, including improved street lighting projects. While methodological problems render the results of the projects statistically questionable, the proliferation of encouraging reports does seem, in itself, significant. However, as cautioned by the National Advisory Commission in 1973 [A.2-92, p. 199],

> ...these statistics cannot be interpreted as proof of the efficacy of lighting programs in reducing crime...additional scrutiny of these results is necessary. Such study will have to take into account the effects of such variables as police patrol levels, displacement of criminal activity to other times and places, and seasonal changes in crime patterns. Until all evidence is

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* For convenience, all references in this report are coded and identified in square brackets. The codes are keyed to the exhibits in Appendix A and refer to the sequence number within each exhibit.

> sifted, it should be assumed that lighting is only one of the factors that help reduce crime.

In more recent months, the LEAA has been subjected to considerable criticism for funding hardware-related projects -- including street lighting projects* -- and for not being able to show that they have contributed to any reduction in crime. The critics have also complained that even though elaborate evaluation requirements are built in at every level of the LEAA program, evaluations have been geared more to justifying past projects than to identifying problems [A.2-10, A.2-115].

The National Institute of Law Enforcement and Criminal Justice (NILECJ), the research arm of the LEAA, has sponsored several evaluation programs which address these doubts and criticisms. Among these is the National Evaluation Program (NEP), which attempts to [A.2-76]:

- provide a timely, objective and reliable assessment to Congress and the public of the effectiveness of LEAA's programs;
- extend the present knowledge and technical capability in all aspects of criminal justice;
- test criminal justice standards and goals and, through critical research, refine and evaluate them; and
- provide criminal justice administrators with relevant information which they can use to administer their programs more effectively.

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* It is *estimated* -- based on an extrapolation of data contained in the LEAA Grant Management Information System -- that some 8 to 12 million dollars of LEAA's total budget to date have been spent on street lighting related projects.

To meet the above stated objectives, the NEP supports major research studies to evaluate various areas of criminal justice activity including those LEAA supports through its block grant program. The NILECJ Office of Research Programs, in consultation with the State Planning Agencies and the LEAA Regional and National Offices, selects the topic areas to be evaluated. For each selected topic area, an initial *Phase I* evaluation is conducted. Based primarily on a review of completed evaluations in the topic area and without extensive data collection and analysis efforts, the Phase I evaluation effort provides a quick but pertinent assessment of the topic area and identifies alternate strategies and designs for further evaluation. If a more *intensive* evaluation is warranted, then a longer term *Phase II* evaluation is conducted.

The topic area of this study is, of course, street lighting, and it is a "Phase I Evaluation of Street Lighting Projects." As an NEP Phase I study, the purpose of the study is to determine the present state of knowledge regarding the impact of street lighting on crime and the fear of crime; this is accomplished by a comparative analysis of past and on-going street lighting projects whose description and impact have either been documented or are easily accessible. More specifically, the study endeavors to:

- review the pertinent issues in street lighting and crime;
- develop an evaluation framework for the comparative analysis of street lighting projects;
- undertake a systematic assessment of available evaluation studies in street lighting;
- outline a single project evaluation design; and

- identify gaps in the present knowledge base and make recommendations concerning future research and evaluation activities which should be undertaken to fill those gaps.

The above five endeavors correspond to the subject matters discussed in Sections 2 through 6, respectively. In this introductory section, the historical development of street lighting is briefly traced in Section 1.1, while the scope of the study is summarized in Section 1.2, and the scope of the report is outlined in Section 1.3.

1.1 HISTORICAL BACKGROUND

Archaeologists have dated outdoor lighting to 3,000 B.C. [A.1-27]. After discovering and mastering fire, prehistoric man used earthen jars to contain the fire which lit his cave inside and out. However, *street lighting systems* are a relatively new phenomenon, dating back to 1558 when the city of Paris installed pitch-burning lanterns on some of its main streets. Street lanterns were just one part of the city's attempt to light up the streets. An ordinance was also passed requiring all citizens to keep lights burning in windows that fronted the streets. It is interesting to note that the lighting of streets in Paris was motivated by the belief that street lighting would rid the streets of nighttime robbers, who practically took over the city after nightfall.

Historically, the motivation for street lighting began with security and safety considerations; then became integrated with the community's need for character identity and vitality; and finally, following the advent of the automobile, contributed to traffic orientation and identification requirements. Exhibit 1.1 summarizes the impact-oriented objectives of street lighting systems; they have remained unchanged for several decades. What has changed over time has been the emphasis placed on the different objectives: for example, security considerations are again high on the list of priorities of urban administrators and planners.

Exhibit 1.1

Impact Objectives of Street Lighting Systems

Security and Safety

- Prevent Crime
- Alleviate Fear of Crime
- Prevent Traffic (Vehicular and Pedestrian) Accidents

Community Character and Vitality

- Promote Social Interaction
- Promote Business and Industry
- Contribute to a Positive Nighttime Visual Image
- Provide a Pleasing Daytime Appearance
- Provide Inspiration for Community Spirit and Growth

Traffic Orientation and Identification

- Provide Visual Information for Vehicular and Pedestrian Traffic
- Facilitate and Direct Vehicular and Pedestrian Traffic Flow

Exhibit 1.2 traces the historical development of street lighting in terms of the types of electric street lighting lamps and the locales where the various street lighting innovations were installed. It is seen that the efficacy* (i.e., lumens per watt) of the electric lamps has increased from less than ten -- for arc lamps -- to over 140 -- for high-pressure sodium vapor lamps -- during the last century. Upon closer examination of Exhibit 1.2, it is also seen that the time between major innovations has become increasingly shorter -- a "future shock" phenomenon. In fact, it is probably safe to say that another major innovation will occur in the very near future. In comparison with present-day high-pressure sodium vapor lamps, the next generation of high-intensity discharge lamps should achieve higher efficacy, longer life, and smaller lamp size (for better optical properties); it should also use multi-vapors which will fill in and perhaps extend the frequency spectrum that characterizes the current set of vapor lamps. Historically, the properties determining the acceptability of new lamp types have been overall output, efficacy, lifetime, ease of maintenance, ease of optical control, color rendition and initial cost.

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* The non-technical reader should peruse Appendix B, which contains an abbreviated, technical discussion of light measures. In any discussion of street lighting, especially in the development and evaluation of street lighting, it is important to have at least a minimum level of technical understanding of street light design and measurement.

Exhibit 1.2

Historical Development of Street Lighting

Lamp Description	Date	Rated Life for Street Lighting Service	Initial Lumens Per Watt
Arc			
Open carbon-arc	1879	Daily trimming	--
Enclosed arc	1893	Weekly trimming	4-7
Flaming arc			
Open	--	12 hours	8.5 (d-c multiple)
Enclosed	--	100 hours	19 (a-c series)
Magnetite (d-c series "luminous arc")	1904	100-350 hours	10-20
Filament			
Carbonized bamboo	1879	--	2
Carbonized cellulose	1891	--	3
Metallized (gem)	1905	--	4
Tantalum (d-c multiple circuit)	--	--	5
Tungsten (brittle)	1907	--	--
Drawn Tungsten	1911	--	9
	1913	--	10
Mazda C (gas-filled)	1930	--	14-20
	1915	1,350 hours	10-20
	1950	2,000 hours	16-21
		3,000 hours	16-20
Mercury Vapor			
Cooper-Hewitt	1901	Indefinite	13
H33-1CD/E	1947	3,000 hours	50
H33-1CD/E	1952	5,000 hours	50
H33-1CD/E	1966	16,000 hours	51
H36-15GV	1966	16,000 hours	56.5
Low-Pressure Sodium			
NA 4 (10,000 lumen)	1934	1,350 hours	50
NA 9 (10,000 lumen)	1935	2,000 hours	56
	1952	4,000 hours	58
	1975	--	180
Fluorescent			
F100T12/CW/RS	1952	7,500 hours	66
F100T12/CW/RS	1966	10,000 hours	71
F72PG17/CW	1966	14,000 hours	68
F72T10/CW	1966	9,000 hours	63
High-Pressure Sodium			
	1965	6,000 hours	Over 100
	1975	15,000 hours	140

(a) Electric Street Lighting Lamps

Date	Place	Light Source/Lamp
1558	Paris, France	Pitch-burning lanterns, followed by candle lanterns
1690	Boston, Massachusetts	Fire baskets
1807	London, England	Gaslights
1879	Cleveland, Ohio	Brush arc lamps
1905	Los Angeles, California	Incandescent
1935	Philadelphia, Pennsylvania	Mercury vapor
1937	San Francisco, California	Low-pressure sodium
1952	Detroit, Michigan	Fluorescent
1967	Several U.S. Cities	High-pressure sodium

(b) Street Lighting Innovations

Sources: [A.2-4, A.2-26]

1.2 SCOPE OF STUDY

The scope of this study can best be understood by first reviewing the approach used in carrying out the study and, secondly, identifying the process by which the sample of street lighting projects was selected.

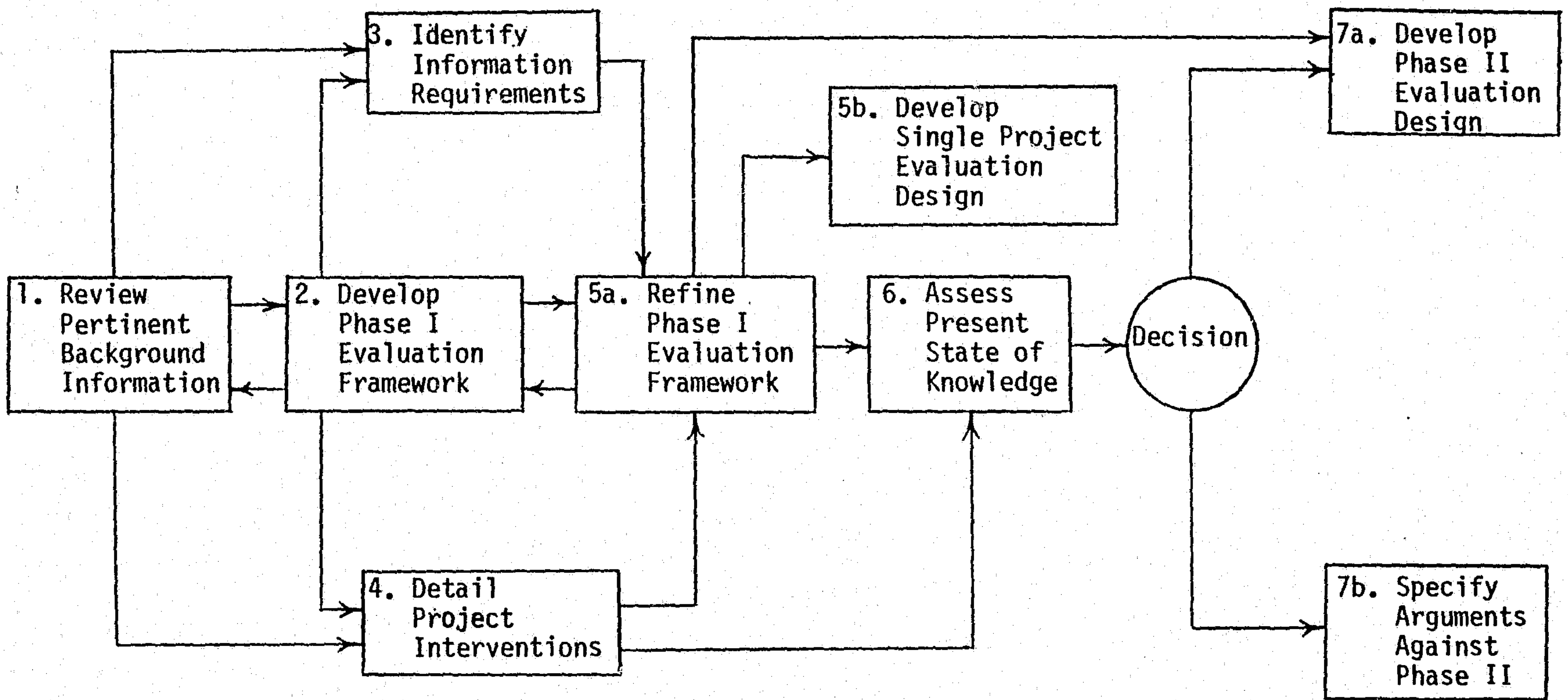
STUDY APPROACH

In carrying out the mandate of the National Evaluation Program in connection with the "Phase I Evaluation of Street Lighting Projects," a study approach was initially proposed; it has since been followed without any deviation and found to be quite adequate. The approach is detailed in Exhibit 1.3; it consists essentially of seven tasks.

The first task of reviewing pertinent background information on street lighting projects contributed to the ensuing three tasks of developing a Phase I (i.e., multi-project) evaluation framework, identifying the types of information required for the study, and detailing project interventions, respectively. The second, third and fourth tasks in turn provided the basis for accomplishing the fifth task, which refined the multi-project evaluation framework and developed a single-project evaluation design. Analyzing the project interventions in terms of the refined multi-project evaluation framework was the purpose of the sixth task, which resulted in an assessment of the present state of knowledge regarding the impact of street lighting on crime and the fear of crime. In the terminology of the National Evaluation Program, the seventh task

Exhibit 1.3

Phase I Study Approach



was to address the possibility of conducting a Phase II evaluation of street lighting projects; that is, to make recommendations concerning future research and evaluation activities which should be undertaken to fill the gaps that exist in the present state of knowledge. Each task is discussed in greater detail below.

Task 1: Review Pertinent Background Information

Based on an encompassing literature survey, an extensive telephone survey, and a limited site survey, this task reviewed the available descriptions, research findings, and evaluation studies of past and on-going street lighting projects; assimilated the opinions of street lighting experts, planners, and users; and analyzed other related background material. The literature survey included using the National Criminal Justice Reference Service (NCJRS), the National Technical Information Service (NTIS), and the LEAA Grant Management Information System (GMIS); surveying the LEAA State Planning Agencies and Regional Offices; and culling through utility company publications and trade journals.

As illustrated in Exhibit 1.3, the review of background material also contributed to the development of a robust and flexible Phase I evaluation framework. In turn, the development of the framework impacted the review task, providing guidance on the type of additional material that was to be culled and reviewed, assuming that the material was accessible. The development of the evaluation framework is discussed next.

Task 2: Develop Phase I Evaluation Framework

As indicated in Exhibit 1.3, the establishment of a Phase I evaluation framework is the result of a series of identical steps, each involving a development and refinement cycle. In general, a single project evaluation framework is a multi-dimensional, systemic structure used to represent the impact of a single project. However, a Phase I evaluation framework is actually a *multi-project* evaluation framework; it must therefore serve an additional purpose -- that of *comparing* similar projects so as to test the validity of the various assumptions and/or hypotheses. "Similar" projects refer to those projects that have common input elements. For example, street lighting projects that are implemented in commercial areas may not be similar to those that are implemented in residential areas. For this reason, more than one evaluation framework may be required for conducting a general Phase I evaluation. On the other hand, the Phase I evaluation is strengthened if a single robust evaluation framework can be developed. Such an evaluation framework is identified in Section 3.

Task 3: Identify Information Requirements

In accordance with the NEP instructions, a user statement was jointly developed with the NEP; it provided answers to such questions as how far to go in collecting data, what sample sizes are necessary, how much detail to include in project intervention diagrams, how sophisticated a Phase I evaluation design is necessary, etc. This user statement helped to refine the Phase I evaluation framework.

Task 4: Detail Project Interventions

For each street lighting project that was deemed within the scope of the topic area and had pertinent crime-related information, a flow diagram of the *actual* chain of activities, hypotheses, interventions and outcomes was developed, including an accompanying narrative that described the diagram, specified the possible intervening variables, and documented the associated input, process and output measures. The output of this task was formally delivered to the NEP during the course of the study; a general discussion of this output is contained in Section 4.

The objective detailing of each project relied on information obtained from published documents, formal telephone interviews and structured site visits. A knowledge of the project interventions helped to refine the Phase I evaluation framework, which is considered next.

Task 5: Refine Phase I Evaluation Framework/ Develop Single Project Evaluation Design

As stated earlier, the Phase I evaluation framework developed in Task 2 underwent a series of refinements -- the final version was the one used both to analyze the pertinent street lighting projects (i.e., as required in Task 4) and to test the various assumptions and/or hypotheses (i.e., as a necessary input to Task 6, which assessed the present state of knowledge). However, as discussed in Section 3, the paucity of reliable and uniform data and the inadequacy of available evaluation studies have minimized both the need and the potential for developing a sophisticated Phase I evaluation framework. Thus, the framework documented in Section 3 is hypothesized and has not been definitively tested by this study, inasmuch as the information regarding existing street lighting projects is neither detailed nor reliable enough to perform such a definitive analysis.

Similarly, the single project evaluation design that has been developed from the evaluation framework is also *untested*. Section 4 contains a description of the single project evaluation design.

Task 6: Assess Present State of Knowledge

The assessment of the present state of knowledge is based on the refined Phase I evaluation framework, as applied to the various street lighting projects. As required by the NEP, the assessment has determined the range of performance and effectiveness of each street lighting project; the accuracy and reliability of the project findings; the factors that seem most likely to influence the success or failure of projects; and the gaps existent in the present knowledge base, the reasons for them, and their impact on the assessment.

The results of this assessment task are primarily documented in Sections 2, 4 and 6. As depicted in Exhibit 1.3, another result of this task is a decision regarding the feasibility and reliability of undertaking an NEP Phase II evaluation effort in the street lighting topic area. Section 6 argues against such an intensive evaluation effort *at this time*.

Task 7: Address Phase II Evaluation

Although a Phase II evaluation is not recommended at this time, a number of related research steps are recommended. Thus, in addition to arguing against a Phase II effort, this task also undertook a systematic review of possible research and evaluation activities whose conduct would allow for a more reliable judgement regarding the effectiveness of street lighting as an anti-crime strategy. The recommendations resulting from this task are contained in Section 6.3.

SAMPLE SELECTION PROCESS

In identifying a sample of street lighting projects for this study, several problems arose in the very definition of what is meant by a *project*. In many locally-funded street lighting efforts, a continuous upgrading process is underway, so that it is almost impossible to identify a project, based on its geographical boundaries and/or time limits. Moreover, even when a project can be identified, there are problems in securing pertinent project-related data since (a) the process of effecting a street lighting project is usually diffuse with responsibilities spread among many different individuals and organizations, and (b) the project, when completed, loses its administrative identity and becomes an inconsequential part of the total system. Additionally, inasmuch as street lighting is designed to satisfy a wide range of objectives -- see Exhibit 1.1 -- including crime prevention, it was difficult to determine if any crime-related data were collected as a part of the project effort. Frequently, crime prevention is used only as a label to secure appropriate LEAA funding. Consequently, unlike other NEP Phase I topic areas (e.g., operation identification, neighborhood team policing, specialized patrol, pretrial release, treatment alternatives to street crime, juvenile diversion, etc.), street lighting is *not* a well defined criminal justice related topic area. The resultant problems are further elaborated on in Section 2.

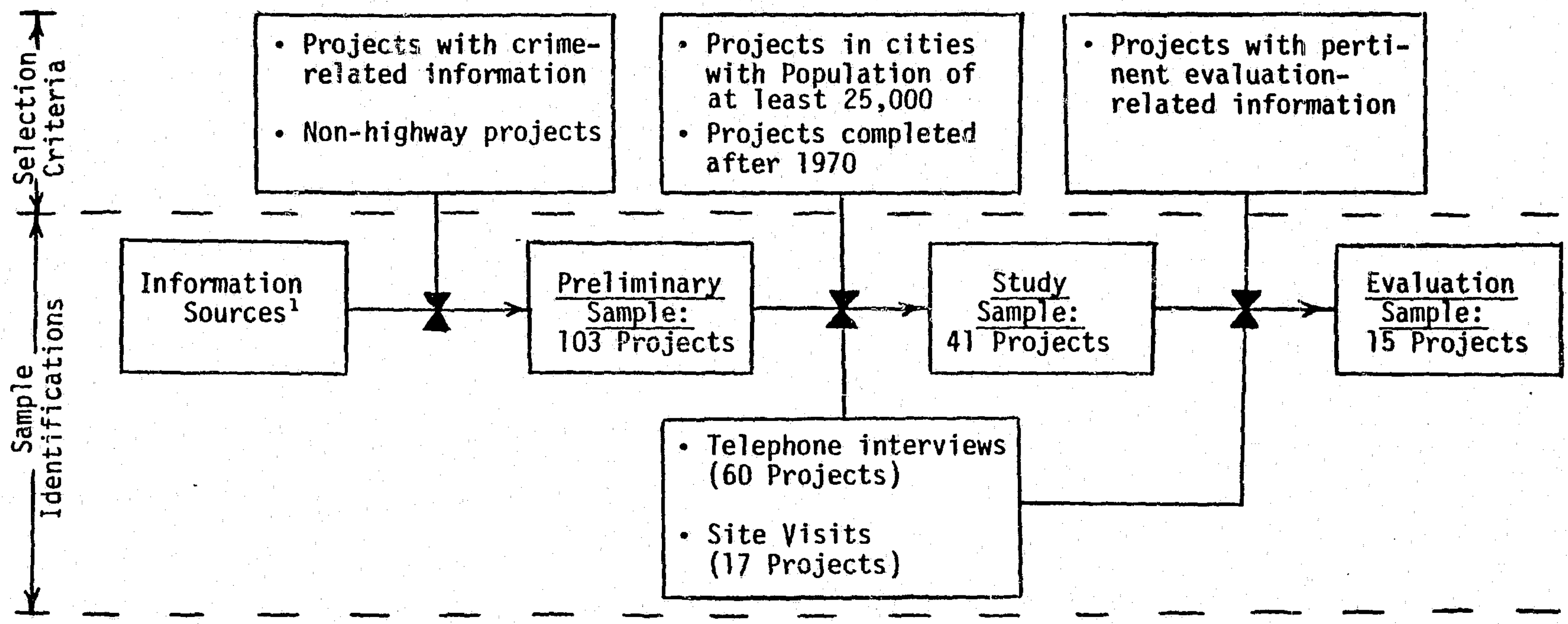
The actual selection of street lighting projects for this study was based on five specific criteria. First, for obvious reasons, only projects with crime-related information were selected. As a result of this first criterion, nearly all of the LEAA-funded projects (i.e., funded through either its block grant or discretionary funding mechanisms) were selected; projects funded by other federal, state or local sources (e.g., Department of Transportation, Department of Housing and Urban Development, bond issues, civic organizations, etc.) usually do not have a crime-related focus. Second, all highway lighting projects were excluded since they were primarily concerned with vehicular safety, not pedestrian security, issues. Third, for reasons of comparability, only projects in cities with population of at least 25,000 were selected. Fourth, after several unsuccessful attempts at securing pre-1970 data, it was decided that only projects completed after 1970 would be studied. Fifth, for the purpose of detailed evaluative analysis, only projects with pertinent evaluation-related information were considered.

Although the above five criteria were essential in the selection of street lighting projects, they were applied at different points in the selection process. In fact, as illustrated in Exhibit 1.4, application of the first two criteria resulted in a *Preliminary Sample* of 103 projects. The subsequent application of the next two criteria resulted in a *Study Sample* of 41 projects, and application of the fifth and final criterion yielded an *Evaluation Sample* of 15 projects. The Preliminary Sample provided some background information; the more detailed Study Sample provided the basis for studying specific issues in street lighting and crime; and the Evaluation Sample provided evaluation-related information.

Exhibit 1.4 also contains a list of information sources. In addition to these sources, telephone interviews were conducted of 60 projects and site visits were made to 17 projects. The projects which were interviewed and/or visited are indicated in Exhibit 1.5, which identifies all the street lighting projects in the Preliminary Sample. It should be noted that several of the projects in the Preliminary Sample were eliminated after telephone interviews suggested that either there was no project as indicated (e.g., no project could be identified in Phoenix, Arizona), or there was a project but the wrong city was indicated (e.g., the Charlotte, North Carolina project was actually located in Gastonia, North Carolina), or the officials interviewed could only recall the most recent project in their city (e.g., Baltimore, Maryland officials could only recall the most recent of the three projects listed in the Preliminary Sample), or no appropriate city officials could be

Exhibit 1.4

Street Lighting Projects: Sample Selection Process



[1] Sources include National Criminal Justice Reference Service (NCJRS), National Technical Information Service (NTIS), LEAA Grant Management Information System (GMIS), survey of LEAA State Planning Agencies and Regional Offices, utility company publications, trade journals, and referrals.

Exhibit 1.5

Street Lighting Projects: Preliminary Sample

City	1970 Population	Project Dates [1]	Phone Survey No	Phone Survey Yes	Site Visit No	Site Visit Yes	Study Sample No	Study Sample Yes
1. Arlington, MA	53,534	1966-1971		x	x			x
2. Asbury Park, NJ	16,533	1971-1974	x		x		x	
3. Asheville, NC	57,681	1973		x	x			x
4. Atlanta, GA	497,421	1973		x		x	x	
5. Atlanta, GA	497,421	1973-1974		x		x		x
6. Baltimore, MD	905,759	before 1971	x		x		x	
7. Baltimore, MD	905,759	1972-1974		x	x		x	
8. Baltimore, MD	905,759	1973-1974		x	x			x
9. Benkelman, NE	1,349	1969-1971	x		x		x	
10. Boston, MA	641,071	1975-1977		x		x		x
11. Burlington, MA	21,980	1969-1974	x		x		x	
12. Charleston, WV	71,505	1968-1974	x		x		x	
13. Charlotte, NC	241,178	1971-1973		x	x		x	
14. Chatanooga, TN	119,082	1972		x	x			x
15. Chicago, IL	3,369,359	1966		x		x	x	
16. Chicago, IL	3,369,359	after 1971		x		x	x	
17. Chicago, IL	3,369,359	1974-1975		x		x		x
18. Cincinatti, OH	452,524	1970-1977		x	x			x
19. Cleveland, OH	750,879	1973-1975		x		x		x
20. Dade County, FL	1,267,792	1972		x		x	x	
21. Danville, IL	42,570	1971-1975	x		x		x	
22. Denver, CO	514,678	1975-1976		x		x		x
23. Detroit, MI	1,512,893	1968	x		x		x	
24. Detroit, MI	1,512,893	1973		x	x			x
25. Durham, NC	95,438	1969-1970		x	x		x	
26. Durham, NC	95,438	before 1974		x	x		x	
27. East Orange, NJ	75,471	1971-1973		x	x			x
28. Flint, MI	193,317	1956	x		x		x	
29. Foster City, CA	9,327	not available	x		x		x	
30. Fort Wayne, IN	178,021	not available		x	x		x	
31. Garland, TX	81,437	1976-1977		x	x			x
32. Gary, IN	175,415	1953-1955	x		x		x	
33. Gastonia, NC	47,142	1971-1973		x	x			x
34. Greendale, WI	15,089	before 1971	x		x		x	
35. Gulfport, MS	40,791	not available	x		x		x	
36. Harrisburg, PA	68,061	1975-1976		x	x			x
37. Indianapolis, IN	745,739	1963-1970		x	x			x
38. Jeffersontown, KY	9,701	1973-1976		x		x	x	
39. Kansas City, MO	507,330	1967-1969	x		x		x	
40. Kansas City, MO	507,330	1971-1972		x	x			x

[1] Calendar years during which planning and installation activities were supposed to have taken place.

Exhibit 1.5

(page 2 of 3)

City	1970 Population	Project Dates[1]	Phone Survey		Site Visit		Study Sample	
			No	Yes	No	Yes	No	Yes
41. Kinston, NC	22,309	1972-1973	x		x		x	
42. Knoxville, TN	174,587	1974		x	x		x	
43. Manchester, NH	87,754	1975		x	x			x
44. McPherson, KS	10,851	before 1960	x		x		x	
45. Miami, FL	334,859	1961-1968	x		x		x	
46. Miami, FL	334,859	1971-1972	x		x		x	
47. Miami, FL	334,859	1972-1977		x		x		x
48. Miami Beach, FL	87,072	1973		x		x		x
49. Midlothian, IL	15,939	1975-1977	x		x		x	
50. Milton, MA	27,190	1971-1974		x	x			x
51. Milwaukee, WI	717,372	1972		x	x			x
52. Montclair, NJ	44,043	1973-1974	x		x		x	
53. Neptune, NJ	5,502	1971-1972	x		x		x	
54. Neptune, NJ	5,502	1972-1974	x		x		x	
55. Newark, NJ	381,930	1969-1970	x		x		x	
56. Newark, NJ	381,930	1973-1974		x		x		x
57. Newark, NJ	381,930	not available	x		x		x	
58. New Kensington, PA	20,312	1974-1975	x		x		x	
59. New Kensington, PA	20,312	1975-1976	x		x		x	
60. New Orleans, LA	593,471	1973-1975		x		x		x
61. New York, NY	7,895,563	1957	x		x		x	
62. New York, NY	7,895,563	1959-1961	x		x		x	
63. New York, NY	7,895,563	1960-1966	x		x		x	
64. New York, NY	7,895,563	1965	x		x		x	
65. New York, NY	7,895,563	1972-1973		x	x		x	
66. New York, NY	7,895,563	after 1973		x	x		x	
67. New York, NY	7,895,563	not available		x	x			x
68. Norfolk, VA	307,951	1972-1974		x	x			x
69. Norman, OK	52,117	1973		x	x			x
70. Norristown, PA	38,169	1974-1975	x		x		x	
71. Oakland, CA	361,561	before 1970	x		x		x	
72. Oak Park, IL	62,511	before 1973		x	x		x	
73. Owensboro, KY	50,329	1968-1970	x		x		x	
74. Passaic, NJ	55,124	1973-1974		x	x			x
75. Paterson, NJ	144,824	1973-1974		x	x			x
76. Peabody, MA	48,080	1974-1977		x	x			x
77. Philadelphia, PA	1,950,098	1975-1976		x	x			x
78. Phoenix, AZ	581,562	not available		x	x		x	
79. Pigeon Forge, TN	1,361	not available	x		x		x	
80. Plainfield, NJ	46,862	1970	x		x		x	

Exhibit 1.5

(page 3 of 3)

City	1970 Population	Project Dates[1]	Phone Survey		Site Visit		Study Sample	
			No	Yes	No	Yes	No	Yes
81. Plainfield, NJ	46,862	1972-1973	x		x		x	
82. Portland, OR	380,620	1972-1973		x	x			x
83. Portland, OR	380,620	1975-1976		x		x		x
84. Raleigh, NC	123,793	1974-1975		x	x		x	
85. Richmond, VA	249,430	1972-1973		x	x			x
86. Rocky Mount, NC	34,284	1969-1970	x		x		x	
87. Salem, OR	68,296	1973		x	x			x
88. Salley, SC	450	1970	x		x		x	
89. San Juan, PR	452,749	1973-1974		x	x		x	
90. Savannah, GA	118,349	1970-1975		x	x			x
91. St. Louis, MO	622,236	1962-1964	x		x		x	
92. St. Louis, MO	622,236	1964-1974	x		x		x	
93. Tampa, FL	277,767	1970-1975		x	x			x
94. Tucson, AZ	262,933	1971		x	x			x
95. Tucson, AZ	262,933	1971-1972		x	x		x	
96. Vincennes, IN	19,867	not available	x		x		x	
97. Wadesboro, NC	3,977	not available	x		x		x	
98. Wake Forest, NC	3,148	1971-1972	x		x		x	
99. Washington, DC	756,510	1970		x		x		x
100. Washington, DC	756,510	1971-1972		x		x	x	
101. Washington, NC	8,961	1973-1974	x		x		x	
102. Watertown, MA	39,307	1966-1971		x	x			x
103. Wichita Falls, TX	96,265	1975-1976		x	x			x

contacted following repeated attempts (e.g., no contact could be made with officials in Oak Park, Illinois). The Study and Evaluation Samples are discussed at length in Sections 2 and 4, respectively.

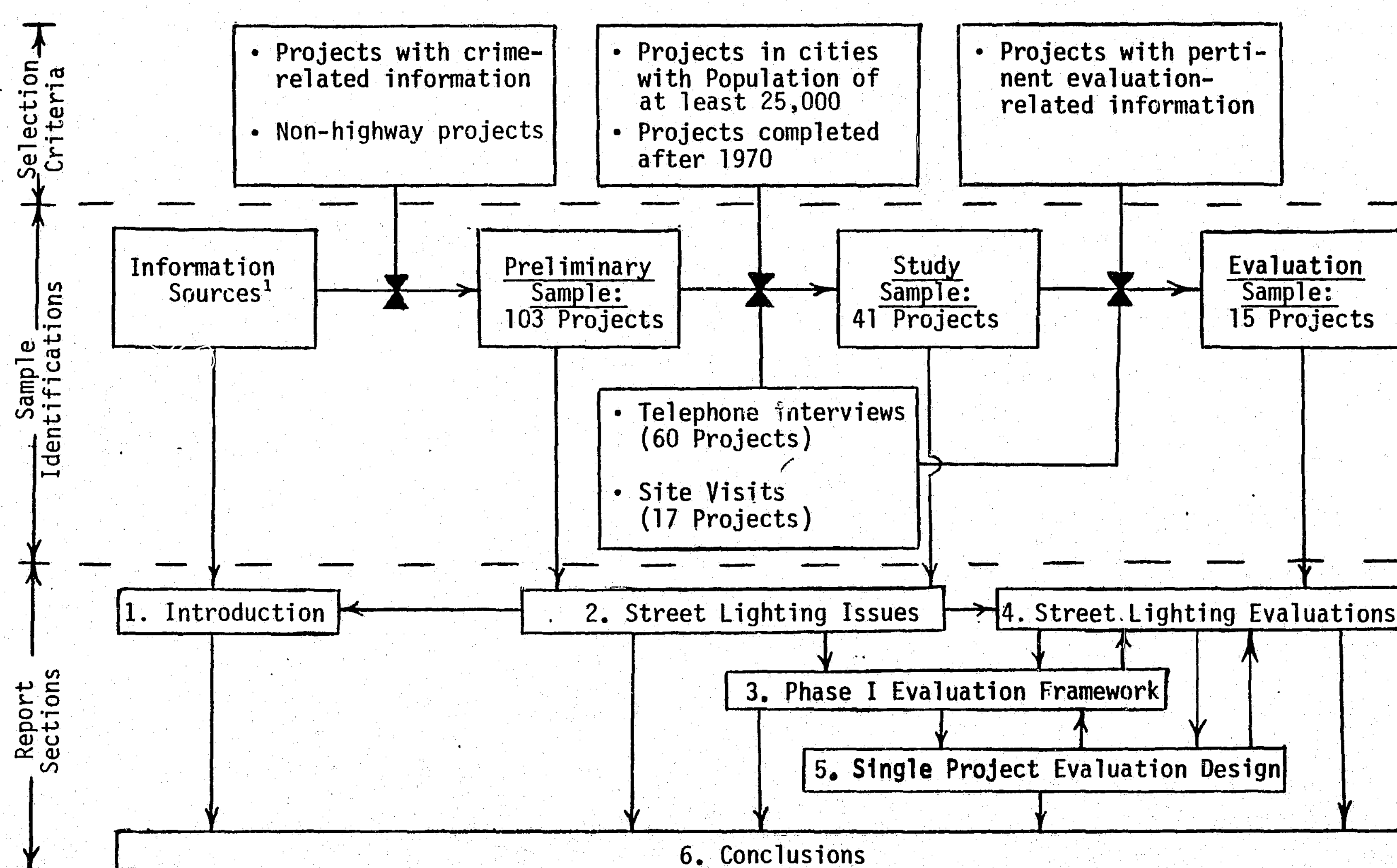
1.3 SCOPE OF REPORT

The scope of this report can best be viewed in terms of the sample selection process, as indicated in Exhibit 1.6. Following the introductory section, Section 2 discusses the issues in street lighting and crime, based on information contained in the Preliminary and Study Samples. These issues contribute to the Phase I evaluation framework that is developed in Section 3. Using the evaluation framework, an analysis of street lighting evaluations is undertaken in Section 4, based on information contained in the Evaluation Sample. A single project evaluation design is developed in Section 5, guided by the Phase I evaluation framework and the analysis of street lighting evaluations. Lastly, the conclusions section, Section 6, summarizes the present state of knowledge; identifies the gaps in the knowledge base; and recommends future research and evaluation activities which should be undertaken to fill those gaps.

There are also three appendices in the report. The first, Appendix A, contains a list of references, including individuals who have been contacted either by telephone, in person, or through written correspondence. Appendix B, as indicated earlier, contains a somewhat technical discussion of light measures. And Appendix C contains the survey instruments which were developed and used in this study.

Exhibit 1.6

Sample Selection Process and Scope of Report



[1] Sources include National Criminal Justice Reference Service (NCJRS), National Technical Information Service (NTIS), LEAA Grant Management Information System (GMIS), survey of LEAA State Planning Agencies and Regional Offices, utility company publications, trade journals, and referrals.

Throughout this report the reader will note that frequent references are made to the Kansas City street lighting study [A.1-30], and often in a critical context. This is not meant to imply that the authors regard it more negatively than the other studies. On the contrary, it stands as the single best evaluation conducted to date on the subject of street lighting and crime, and provides the single most detailed body of material for the wide range of critiques contained in this report.

Finally, the content of this report should be of interest to both criminal justice administrators and planners, as well as professionals engaged in the technical aspects of designing, installing or maintaining street lighting systems. The administrator who is concerned with the funding of street lighting projects should read Section 6. The planner or engineer who is developing a street lighting project should read Sections 2, 4 and 6 and also Appendix B; and the planner who is interested in evaluating a street lighting project should, of course, peruse the entire report.

2 STREET LIGHTING ISSUES

As stated in Section 1, street lighting projects are designed to satisfy a wide range of objectives, including crime prevention. Therefore, in a study of street lighting and crime, it is necessary to consider both *street lighting* issues--which influence the determination of a relationship between street lighting and crime--and *evaluation* issues--which focus more directly on the difficulties of establishing such a relationship. The street lighting issues are considered in this section, while the evaluation issues are considered in Section 3.1.

The issues contained herein represent a culling and systematizing of the more important issues that were initially identified in the Preliminary Sample of street lighting projects and subsequently detailed in terms of the projects in the Study Sample. In fact, unless otherwise noted, the material covered in this section is based on the 41 projects which constitute the Study Sample. Although the Study Sample may not be statistically representative of all street lighting projects, it is seen from Exhibit 2.1 that the sample includes projects with a range of characteristics. However, because of the small sample size, *no* elaborate statistical analysis is attempted in this section; such an analysis would be *misleading*. Nevertheless, the issues addressed herein are deemed to be *significant* in a study of street lighting and crime.

Based on the literature, telephone and site visit surveys, a multitude of issues was identified. Guided by the purpose of this

Exhibit 2.1

Street Lighting Projects: Study Sample

City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[3]	Target Area(s)	Project Cost ($1,000)[4]	Light Source(s) Wattage	Light Source(s) Type[5]	Light Source(s) Number	Crime-Related Information Sources Planning Report[6]	Crime-Related Information Sources Evaluation Report[7]	Crime-Related Information Sources Other[8]
1. Arlington, MA	52,881	not available (n.a.)	1973-1974	schools, parks	n.a.	400W 400-1000W	HPS MV	n.a. n.a.			x
2. Asheville, NC	58,765	3,495	1973	central business	37.4/year	400W	HPS	315			x
3. Atlanta, GA	451,123	9,988	1973-1974	central business	293.6	400W	HPS	191	x	x	x
4. Baltimore, MD	880,557	7,433	1973-1974	n.a.	500.0	n.a.	HPS	n.a.		x	x
5. Boston, MA	618,275	8,490	1973-1980	residential, commercial	5,105.0	n.a. n.a.	HPS MV	n.a. n.a.			x
6. Chatanooga, TN	137,957	6,427	1972	central business	35.0/year	1000W	HPS	150			x
7. Chicago, IL	3,172,929	6,761	1974-1975	city-wide	8,000.0	150- 310W	HPS	90,000		x	x
8. Cincinnati, OH	426,245	6,781	1970-1977	central business	1,345.0	1000W	MV	75	x		x

[1]U.S. Bureau of the Census estimates for 1973.

[2]Total Crime Index per 100,000 population--Total Crime Index includes murder, non-negligent manslaughter, forcible rape, robbery, aggravated assault, burglary, larceny, and auto theft.

[3]Calendar years during which planning and installation activities were supposed to have taken place.

[4]*Annual* figures indicate lease rates paid for utility-owned systems. Other figures indicate initial costs for mostly city-owned systems.

[5]FL: fluorescent; HPS: high-pressure sodium; LPS: low-pressure sodium; MH: metal halide; MV: mercury vapor

[6]Includes grant applications.

[7]Includes reports *designated* by the authors or project personnel as an evaluation of the impact of street lighting on crime and/or the fear of crime.

[8]Includes telephone interviews, site visits, annual reports, and pertinent journal articles.

City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[3]	Target Area(s)	Project Cost ($1,000)[4]	Light Source(s) Wattage	Type[5]	Number	Crime-Related Information Sources Planning Report[6]	Evaluation Report[7]	Other[8]
9. Cleveland, OH	678,615	6,210	1973-1975	central business, residential, commercial	423.6	400-1000W	MV	948	x		x
10. Denver, CO	515,593	8,543	1975-1976	residential, commercial, schools	580.0	400W	HPS	1,500	x	x	x
11. Detroit, MI	1,386,817	8,520	1973	central business	1,700.0	250- 400W	HPS	2,500			x
12. East Orange, NJ	74,210	6,279	1971-1973	n.a.	25.0/year	250- 400W	MV	368			x
13. Garland, TX	101,099	3,949	1976-1977	industrial	5.0	400W	HPS	n.a.	x		x
14. Gastonia, NC	48,938	6,827	1971-1973	residential, commercial	46.8	175- 400W	MV	433			x
15. Harrisburg, PA	61,182	8,847	1975-1976	residential, commercial	102.5	100- 250W	HPS	229		x	x
16. Indianapolis, IN	728,344	4,066	1963-1970	city-wide	646.6/year	175-1000W	MV	7,148			x
17. Kansas City, MO	487,799	6,631	1971-1972	central business, residential, commercial	n.a.	400W 175- 400W	HPS MV	594 1,206		x	x
18. Manchester, NH	83,417	4,274	1975	central business	29.1/year	400W	HPS	128			x
19. Miami, FL	353,984	8,580	1972-1977	city-wide	1,600.0/year	250-1000W	HPS	11,700	x	x	x
20. Miami Beach, FL	94,698	4,160	1973	residential, commercial	200.0	n.a. n.a. n.a.	HPS MV MH	n.a. n.a. n.a.	x		x
21. Milton, MA	27,340	2,813	1971-1974	city-wide	220.0/year	100- 400W	MV	2,451			x

Exhibit 2.1

(page 3 of 4)

City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[3]	Target Area(s)	Project Cost ($1,000)[4]	Light Source(s) Wattage	Type[5]	Number	Crime-Related Information Sources Planning Report[6]	Evaluation Report[7]	Other[8]
22. Milwaukee, WI	690,685	4,419	1972	residential	130.0	250W	HPS	130		x	x
23. Newark, NJ	367,683	8,489	1973-1974	residential, commercial	137.0	175- 250W	MV	762	x	x	x
24. New Orleans, LA	573,479	6,138	1973-1975	residential	7.0	400W	MV	559		x	x
25. New York, NY	7,646,818	6,223	n.a.	industrial	n.a.	n.a.	LPS	n.a.			x
26. Norfolk, VA	283,064	6,060	1972-1974	residential	100.0	100W	MV	n.a.		x	x
27. Norman, OK	58,910	5,194	1973	commercial	n.a.	n.a.	HPS	28	x		x
28. Passaic, NJ	53,777	7,260	1973-1974	residential	25.0	100- 400W	MV	302			x
29. Paterson, NJ	143,372	8,727	1973-1974	central business, residential	24.0	400W 400W 400W	HPS MV FL	80 1,184 266			x
30. Peabody, MA	47,857	3,653	1974-1977	central business, arterial streets	12.4/year	250W	HPS	358			x
31. Philadelphia, PA	1,861,719	3,882	1975-1976	city-wide	2,000.0	70- 400W	HPS	78,000			x
32. Portland, OR	375,948	9,673	1972-1973	residential	250.0	175W	MV	330		x	x
33. Portland, OR	375,948	9,673	1975-1976	residential, commercial	447.8	250W 175- 400W	HPS MV	152 287	x		x
34. Richmond, VA	238,087	6,418	1972-1973	residential, commercial	276.0	250W 175- 400W	HPS MV	404 457		x	x
35. Salem, OR	79,247	6,240	1973	central business	22.0/year	400W	HPS	224			x

Exhibit 2.1

(page 4 of 4)

City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[3]	Target Area(s)	Project Cost ($1,000)[4]	Light Source(s) Wattage	Type[5]	Number	Crime-Related Information Sources Planning Report[6]	Evaluation Report[7]	Other[8]
36. Savannah, GA	105,768	7,142	1970-1974	residential, commercial	364.5/year	250- 400W 175-1000W	HPS MV	1,700 5,300			x
37. Tampa, FL	275,643	8,922	1970-1975	central business	127.7/year	1000W	MH	450			x
38. Tucson, AZ	307,551	6,859	1971	residential	45.0	175W	MV	277		x	x
39. Washington, DC	734,801	6,946	1970	residential, commercial	365.0	250- 400W	HPS	n.a.		x	x
40. Watertown, MA	37,436	3,318	1966-1971	city-wide	144.0/year	100- 400W	MV	2,079			x
41. Wichita Falls, TX	95,501	4,529	1975-1976	residential, commercial	109.5	250- 400W	HPS	600	x		x

study, however, it became apparent that there are seven significant street lighting issues which merit consideration. The first two issues--project responsibility and project funding--identify the context in which a new street lighting *project* is developed. The second two issues--system design and system measurement--identify the street lighting *system* that is actually created by the project. Finally, there are three *related* issues--energy considerations, legal considerations, and environmental considerations--which can impact the design and operation of the street lighting system. The following three subsections discuss the project, system and related issues, respectively. Although the discussion is primarily focused on the problems and gaps that the issues cause in the understanding of street lighting and crime, it also contains some descriptive background information which is necessary in order to comprehend the significance of some of the issues. *Recommendations* on how to best overcome these problems and gaps are summarized in Section 6.2.

2.1 PROJECT ISSUES

The nature of a street lighting project is for the most part determined by those who are *responsible* for the project and the mandate of the *funding* source.

PROJECT RESPONSIBILITY

Every street lighting project, especially a crime-related project, involves a division of responsibility between a number of different city agencies and outside contractors. As illustrated in Exhibit 2.2, the involvement of each participant can occur at different stages in

Exhibit 2.2

Involvement of Street Lighting Participants

Project Participants	Project Stage		
	Planning	Installation/ Operation	Evaluation
Public Officials (Mayor; City Manager; City Council; Board of Aldermen; Selectmen)	X		
Engineering Departments (Public Works; Streets; Traffic; Transportation Department)	X	X	X
Utility Companies (Publicly or Privately Owned Electric Utility)	X	X	
Law Enforcement/Criminal Justice Agencies (Police Department; Criminal Justice Coordinating Council)	X		X
Planning and Development Agencies (Community Development Department; Urban Renewal Authority; Model City Agency; Planning Department)	X		X
Public Property Departments (Parks; Forestry; Real Property Department)	X	X	
Administrative Services Departments (Purchasing Agent; Grant Management Agency; Data Processing Department)	X		X
Other Private Sector Participants (Consultant; Contractor; Civic Organization; Materials Supplier)	X	X	X

the development of the project. In any one project, the planning stage could involve the participation of as many as five different agencies and contractors. For example, the city manager or mayor could be attempting to constrain the selection of the project target area, while the public works department is determining the exact type and location of the street lights. Meanwhile, the utility company may be providing technical data on the power circuits or on the available hardware, and the criminal justice planning agency is providing crime statistics to support the selection of a target area. Finally, the forestry department may be providing information necessary for the preservation of existing trees or scheduling tree pruning operations to complement the installation of lighting.

In practice, the city agency with primary responsibility for providing street lighting services shares this responsibility with a privately- or publicly-owned utility company, according to one of the following three ownership/maintenance configurations:

- municipality owns and maintains the street lighting system, and the utility provides power to the system;
- municipality owns the system, and the utility provides maintenance and power; or
- utility owns, maintains and supplies power to the system, charging a rate to the municipality which includes amortization of capital investment, maintenance and energy expenses.

Exhibit 2.3 shows the representation of these three configurations within the Study Sample, and indicates the tendency for *large* cities to own and maintain their systems, and for *smaller* cities to rely on

Exhibit 2.3

Street Lighting Project Ownership/
Maintenance Configurations

Ownership/ Maintenance Configuration	No. of Projects in Cities with Population:			
	Less Than 100,000	100,000-500,000	More Than 500,000	Total
Municipally Owned/ Municipally Maintained	3	5	8	16
Municipally Owned/ Utility Maintained	1	2	2[1]	5
Utility Owned/ Utility Maintained	10[2]	6	2	18
No Information	0	2	0	2
TOTAL	14	15	12	41

[1] Both utilities are publicly-owned.

[2] Includes one publicly-owned utility.

a utility company--which often covers an entire region or state--for ownership and maintenance.

In general, then, the primary city agency typically relies on a number of other city agencies for various tasks, and often engages private sector consultants and contractors to perform some of these tasks. As a result, a project to install or upgrade all or a portion of a city's street lighting system may have responsibility for different activities so *diffused* that it causes severe problems in *project coordination* and *data acquisition*. These problems in turn may affect or "explain" the findings of both single-project and multi-project evaluations. For example, the lack of project coordination may result in the non-compliance with project plans which would invalidate the evaluation design.

Project Coordination is Lacking

In a crime-related street lighting project, where many decisions are arrived at through the consensus of several agencies, and where vital work is performed by agencies not formally reporting to the principal street lighting agency, it is, of course, important to coordinate all aspects of the project. Political reality makes the task of inter-agency coordination even more difficult; sometimes, different agencies are responsible to different members of the city council.

The lack of project coordination has caused misunderstandings, project plan changes, long delays and, in a few cases, project cancellations. In one instance, the local criminal justice planning agency drew up the entire street lighting proposal by itself; the proposal was funded with LEAA monies but was at first rejected by the public works department as "a totally impractical plan--not at all consistent with the existing street lighting system." After several re-drafts of the proposal and long delays, the project was finally implemented. Actually, several criminal justice planning agencies have had similar experiences. It seems that criminal justice planners are reluctant to contact city engineers because they are unable to communicate with the engineers on a technical level; on the other hand, the city engineers are unfamiliar with crime statistics and are therefore unsympathetic toward installing or upgrading a street lighting system for the purpose of crime prevention.

It is obvious that criminal justice planners must coordinate and communicate with other city agencies in their attempt to develop crime-related street lighting projects. The communication could be facilitated by having some technical knowledge of street light design and measurement. The technical material contained in this report could serve that purpose.

Data Acquisition is Difficult

The diffuseness in project responsibility also causes severe problems in the acquisition of evaluation-related data. The relevant data are located in several different agencies, and the types of data maintained by the different agencies vary from project to project. The project evaluator must therefore depend on the agencies to collect data in the form and quality required for the evaluation.

In practice, the form of the data is governed by the needs of each agency maintaining it, and is not always consistent with the needs of the evaluator. For example, cost data may be divided into initial capital expense and ongoing annual maintenance and energy expenses, or all of the cost elements may be combined in a utility company's annual lease rate, whichdoes not detail the separate contributions of capital, maintenance and energy. While single-project evaluations must adapt to the particular forms in which the data are being maintained, a multi-project evaluation faces an almost impossible task of combining data in different forms into a common framework. The task can be accomplished if the common framework is not required to be detailed, which would of course detract from the significance and usefulness of the multi-project evaluation effort. A better solution is to identify a uniform measures framework which could guide the collection of data in all projects. An initial attempt at such a framework is contained in Section 5.1.

The quality--accuracy, completeness and machine readability--of the data also varies from agency to agency and project to project. Inasmuch as the project evaluator must depend on the willingness of others to collect the data, there is little opportunity to exercise quality control, or even to assume that the data would be available. In Newark, for example, the crime data required for the evaluation were to have been collected by a staff whose salaries were paid out of funds unrelated to the street lighting project or its evaluation. The project evaluator had no responsibility for or authority over the data collection staff, and so was unable to intervene directly when problems curtailed the data collection effort. As a result, reported crime statistics were available for only a part of the evaluation time period that was originally specified in the evaluation design.

PROJECT FUNDING

Street lighting projects can be paid for out of funds derived from federal, state, local and private sources; the major sources are listed in Exhibit 2.4. Sometimes these sources act in tandem, as when federal programs require a local matching share, or when a merchant's association pays the operating expense of a system whose capital cost is borne by the municipal government. Many of the federal government funding sources have changed with the advent of revenue sharing. Thus, the Department of Transportation's TOPICS program and the Department of Housing and Urban Development's Model Cities and Urban Renewal programs are no longer active, while funds now flow via general revenue sharing and Community Development block grants.

The Law Enforcement Assistance Administration (LEAA) has funded lighting programs both directly through discretionary grants to municipalities, and indirectly through block action grants to the states. Unfortunately, there is no available information regarding the exact amount expended by the LEAA for street lighting. However, it is *estimated*--based on an extrapolation of data contained in the LEAA Grant Management Information System--that some 8 to 12 million dollars of LEAA's total budget to date have been spent on street lighting related projects.

Perhaps more important than the amount spent to date by the LEAA on street lighting, is the possible future level of funding. For example, Exhibit 2.5 contains a bill--H.R. 565--which was recently introduced in Congress. Although the bill did not pass, it would have amended the Omnibus Crime Control and Safe Streets Act of 1968 to provide for a 75 percent matching of costs incurred by cities for

Exhibit 2.4

Sources of Funds for Street Lighting Projects

Category	Sources of Funding
Federal	• Department of Transportation (Federal Aid Primary System; TOPICS) • Department of Justice/Law Enforcement Assistance Administration (Block Action Grants; Discretionary Grants; Pilot Cities Program; Impact Cities Program) • Department of Housing and Urban Development (Community Development Block Grants; Neighborhood Development; Historic Preservation; Model Cities; Urban Renewal; Concentrated Code Enforcement; Open Space) • Treasury Department (General Revenue Sharing)
State/Local	• General Funds • Bond Issues • Property Assessment • Redistribution of State Taxes • Special Tax on Income or Luxuries • Investment of Municipal Power Company Profit
Private	• Civic Organizations • Businesses and Merchants' Organizations • Private Citizens

Exhibit 2.5

A Recent Congressional Bill for Improved Street Lighting

94TH CONGRESS
1ST SESSION
JANUARY 14, 1975

H. R. 565

A BILL

To amend the Omnibus Crime Control and Safe Streets Act of 1968 to provide for grants to cities for improved street lighting.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That parts F, G, H, and I of title I of the Omnibus Crime Control and Safe Streets Act of 1968 are redesignated G, H, I, and J, respectively, and such title is further amended by inserting the following new part immediately after part E:

"PART F—LIGHT ON CRIME PROGRAM

"SEC. 461. It is the purpose of this part to encourage units of general local government to provide increased street lighting in urban areas within such limits, by making available direct Federal aid for such increased street lighting.

"SEC. 462. The Administration is authorized to make direct grants, without regard to any comprehensive State plan, to any unit of general local government for the improvement of street lighting systems in any urban place or places in such unit. Such improvement shall include the increased use of bright street lighting, such as high-pressure sodium lamps. Each grant made under this section shall be for an amount not to exceed 75 per centum of the cost of the project with respect to which such grant is made.

"SEC. 463. In addition to any other authorizations of appropriations for the purposes of this Act, there are authorized to be appropriated for the purposes of this part, to remain available until expended, $60,000,000 for the fiscal year ending June 30, 1976, and $60,000,000 for each of the next four fiscal years.".

the purpose of improving street lighting. The total funding authorized by the bill would have been $300 million, over a five-year period. It is interesting to note that no standards or guidelines were established in the proposed legislation to assure that crime prevention objectives are met, other than to require "increased use of bright street lighting, such as high pressure sodium lamps." Section 4, however, presents evidence that the impact of street lighting on crime is not only related to the brightness or the use of any particular light souce but also to various other environmental factors. The further definition and understanding of these relationships will, of course, contribute to the establishment of guidelines necessary for the effective allocation of street lighting funds, thereby increasing the potential effectiveness of such legislation as H.R. 565.

Although the sources for funding street lighting projects are many, each source has, as expected, a different mandate--usually a narrowly focused mandate. For example, the Department of Transportation funds street lighting projects for traffic safety reasons, and the LEAA is interested in crime reduction. As a result, the objectives of a street lighting project are usually *unrealistically narrow* in focus. Furthermore, the LEAA mandate in essence requires that the projects be located in areas with a high incidence of crime. This requirement presents a problem in evaluation, since it encourages the occurrence of *"regression artifacts"* in the analysis of crime statistics. Finally, the desire of funding sources for quick results has--in those few cases where evaluation efforts have been funded*--resulted in evaluations that are *brief* and *inadequate*. The following subsections consider the above stated problems in more detail.

Project Objectives Are Unrealistically Narrow in Focus

The art of securing support from a particular funding source is, of course, to tailor fit the objectives of a proposed project to conform to the funding source's mandate or purpose. In the area of street lighting, the art has been practiced with finesse and success, and street lighting projects funded by different sources have correspondingly different objectives. Thus, the narrow foci of the various funding sources are unrealistically forcing the street lighting projects to assume correspondingly narrow ranges of objectives. What is needed, is for the funding sources to recognize the wide range of street lighting objectives and to pool their resources in support of a more comprehensive and common set of projects.

It is, of course, not obvious that street lighting systems can be designed to meet all of the objectives simultaneously. Apart from an incomplete knowledge of the specifications required for any one objective, there may be conflicts between objectives. For example, it could be supposed that even if very high intensity street lighting in shopping areas is best for the enhancement of business, a resultant visual disorientation and glare could contribute to traffic accidents. Nevertheless, a comprehensive planning approach is needed.

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* Most sources neither require nor support evaluation-related activities as a part of their funding of street lighting projects. The LEAA appears to be the most consistent in its requirement for some evidence of evaluation.

Unfortunately, as might be expected, comprehensive planning is the exception rather than the rule in street lighting. If the overall "streetscape" is chaotic and characterless, it is difficult to coordinate street light designs with the undefined streetscape. Large scale urban renewal programs constitute one of the few instances where both planning and implementing funds are available, and where other activities, such as street reconstruction, housing development and replacement of street signs, are coordinated with lighting installation or upgrading. Even in less ambitious street lighting plans, lighting engineers have seldom seen their carefully planned designs executed according to specifications. Problems which have been cited include substitution of equipment because of price considerations or change of local ordinances; refusal of utility companies to work with innovative designs; and inability of harassed and overworked municipal officials to examine detailed proposals carefully [A.1-59, A.2-84].

An assessment of the 18 LEAA-funded projects in the Study Sample revealed not only that the selection of crime-related objectives was often motivated by the availability of LEAA funds, but also that the detailed expression of these objectives was tailored to the *perceived* requirements of the LEAA. Thus most of the objectives are *quantitatively* stated in terms of one-year reductions of five to 50 percent in the absolute number of reported crimes in the target area. Interestingly, the objectives of the Study Sample projects range from very general statements (e.g., reduce the total reported crime in the relit area by ten percent within one year) to more specific statements (e.g., reduce night street stranger-to-stranger crimes in the relit area by five percent within one year). In short, the objectives do not appear to be rooted in any coherent theory.

Although the LEAA appears to be influencing project planners to express their objectives in a quantitative manner, the arbitrariness of the resultant objectives arises from a more fundamental gap in the theory of *how* street lights affect crime and the fear of crime; it can therefore be expected to persist until evaluations are re-oriented toward developing and testing such a theory. In effect, crime *reduction* is emphasized over crime *prevention* because there is no theory about the mechanisms by which street lighting intervenes in the occurrence or prevention of a crime. The absence of such a theory has made the crime deterrent objective of street lighting a poor last in relation to the other objectives of community character and vitality, and traffic safety, orientation and identification. In the past, most city planners have not even considered security related issues in their designs; they are, however, becoming increasingly aware of the crime issue, primarily through such LEAA-funded programs as the Crime Prevention Through Environmental Design (CPTED) program, which is discussed in Section 2.3.

Possibility of Regression Artifacts in Evaluation

A review of the Study Sample projects shows that 26 of the project target areas were selected because of a high crime rate; this inherently causes a problem in the design of an evaluation, since classical experimental design techniques, which call for *random* selection of experimental and control groups, cannot be applied. As a result, the procedure of selecting a high crime area for treatment could lead to *regression artifacts* in the statistical analysis; that is, if crime rates are fluctuating over time and the treatment or target area was selected at a high point in the fluctuation, it is *likely* that the area would experience a lower crime rate in the next period of time, even if *no* treatment was made. In other words, the tendency of a fluctuating statistic to regress towards its mean is an especially acute problem when the experimental group is selected because it exhibits a pre-treatment value of the statistic that is extreme [A.2-18]. Methods for coping with regression artifacts are considered in Section 5.2.

Evaluation Efforts Are Brief and Inadequate

Most evaluative statements must, by definition, be rendered at the *end* of a project. The period of a street lighting project is usually less than 18 months; that is, the planning, installation, operation and--in those instances where evaluation is funded--evaluation of a project must occur within 18 months. Funding sources are usually loathe to support a long project period; they are eager for quick results. Consequently, any delays in the pre-evaluation stages of a project usually imply a shortening of the evaluation period. Since delays are more the rule than the exception, project evaluation periods have nearly always been shorter than initially planned--sometimes an evaluation is based on one or two months worth of crime statistics. Even if no delays occur, an 18-month project would only allow for a 12-month evaluation effort, which is quite *minimal*.

Budget overruns in the early stages of a project have also curtailed evaluation efforts. In some instances (e.g., Cleveland and Miami Beach projects), evaluation efforts have been cancelled because of budget overruns.

In sum, the requirements of funding sources and the unexpected time delays and budget overruns of project development combine not only to make evaluation efforts brief but also inadequate. What is required is for the funding sources to accept the unexpected and to explicitly support project evaluation efforts--making them mandatory.

2.2 SYSTEM ISSUES

The *design* of a street lighting system specifies what the system ought to be, while the *measurement* of the system reveals its true state. Unfortunately, the existing system designs and measurements are lacking in many respects. Before discussing the design and measurement issues in the following two subsections, respectively, it is helpful first to understand the nature of a street lighting system.

The components of a street lighting system are summarized in Exhibit 2.6, while more detailed characteristics of the major component--light sources or lamp types--are contained in Exhibit 2.7.* Lamps are generally classified according to the physical processes by which they produce light. Incandescent sources contain a thin wire filament

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* For a more complete description of street lighting principles, see [A.2-26].

Exhibit 2.6

Street Lighting Components

Components	Definition	Typical Range of Selected Characteristics
Light Source	A lamp which produces visible energy	• Source Type: Low-pressure sodium (LPS); high-pressure sodium (HPS); metal halide (MH); fluorescent (FL); mercury vapor (MV); and incandescent (in order of decreasing efficacy) • Wattage: 70 to 1,000 watts • Output: 4,000 to 140,000 lumens
Luminaire	A device or fixture which contains, protects and positions a light source, focuses and reflects the light in a given distribution and connects the light source to the electrical system	• Light Distribution: Seven standard horizontal illumination patterns • Glare: Full-, semi- and non-cutoff of glare
Mounting Equipment and Configuration	Poles, foundations and bracket arms supporting luminaires in a given configuration	• Poles: Wood, steel, aluminum, concrete or fiberglass (in order of decreasing frequency of use) • Mounting Height: 10 to 40 feet • Pole Spacing: 50 to 250 feet • Pole Configuration: Opposite, one-sided or staggered
Electrical System	Wiring and transformers to provide electrical power to the luminaires	• Wiring Location: Overhead or underground • Wiring Type: Series or parallel

Exhibit 2.7

Selected Characteristics of Basic Lamp Types

	Lamp Type				
	Incandescent (Including Tungsten Halogen)	High-Intensity Discharge (HID)			
Characteristics		Fluorescent	Mercury Vapor	Metal-Halide	High-Pressure Sodium
Wattages (lamp only)	15 to 1500	40 to 219	40 to 1000	400, 1000, 1500	75, 150, 250, 400, 1000
Life (hours)	750 to 12,000	9000 to 30,000	16,000 to 24,000	1500 to 15,000	10,000 to 20,000
Efficacy (lumens per watt, lamp only)	15 to 25	55 to 88	20 to 63	80 to 100	100 to 130
Color rendition	Very good to excellent	Good to excellent	Poor to very good	Good to very good	Fair
Light direction control	Very good to excellent	Fair	Very good	Very good	Very good
Source size	Compact	Extended	Compact	Compact	Compact
Comparative fixture cost	Low because of simple fixtures	Moderate	Higher than incandescent, generally higher than fluorescent	Generally higher than mercury vapor	Highest
Comparative operating cost	High because of relatively short life and low efficacy	Lower than incandescent; replacement costs higher than HID because of greater number of lamps needed; energy costs generally lower than mercury vapor	Lower than incandescent; replacement costs relatively low because of relatively few fixtures and long lamp life	Generally lower than mercury vapor; fewer fixtures required, but lamp life is shorter and lumen maintenance not quite as good	Generally lowest; fewest fixtures required

Source: [A.2-4]

which heats up and glows upon passage of an electric current. All other sources used in street lighting are called high-intensity or gaseous discharge lamps, and produce light by passing an electric current through a gas, usually containing one or more metal vapors as well as other elements. The effect is to "excite" the atoms of the gas to higher than normal energies. The atoms then discharge this excess energy in the form of light, and the colors of the light are very narrowly defined and specific to the combination of elements in the lamp. Some lamps use phosphorescent coatings on the bulb surface to broaden the range of colors produced. In fact, the discharge in a fluorescent lamp produces mostly invisible ultraviolet light, and these lamps rely on coatings to convert the light into visible colors.

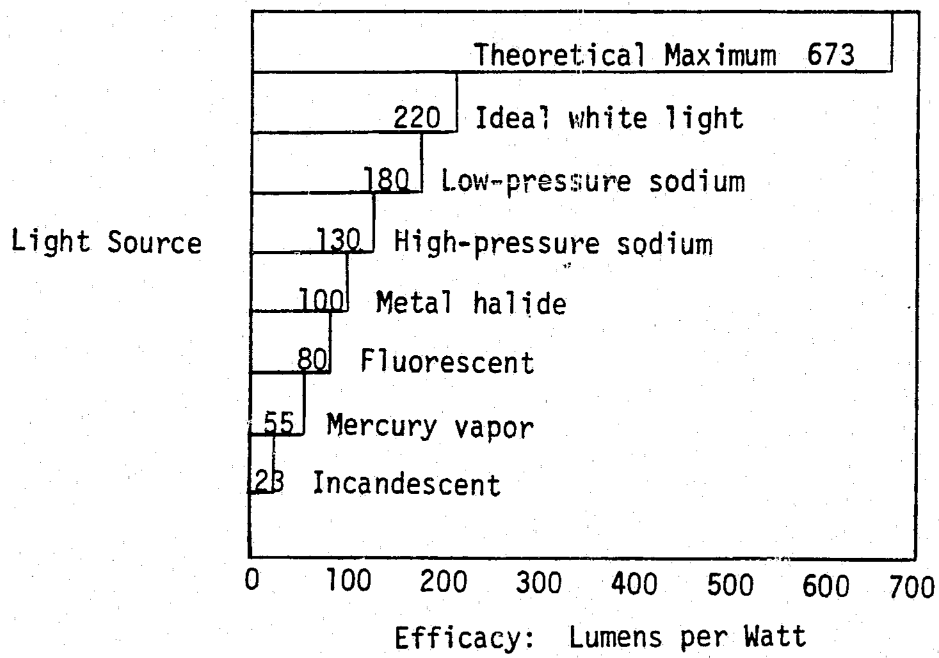
In a discussion of crime-related issues, it is instructive to discuss further two of the lamp characteristics that are identified in Exhibit 2.7--efficacy and color rendition--and also another street lighting component--the luminaire. The term efficacy is used to denote how *efficiently* a lamp converts electrical energy, as measured in watts, into light, as measured in lumens.* It is thus an important factor in a cost-effectiveness consideration of a street lighting system. In general, high-intensity discharge (HID) lamps have higher efficacy than fluorescent bulbs, and, among the HID sources, high-pressure sodium lamps are the highest. One source not used as commonly in the United States as it is in Europe, the low-pressure sodium lamp, has an even higher efficacy than high-pressure sodium. There are,

*See Appendix B for a discussion of light measures.

however, some color rendition problems with low-pressure sodium. The relative efficacies of different light sources are presented in Exhibit 2.8.

Exhibit 2.8

Relative Efficacies of Light Sources



Source: [A.2-4]

Color rendition is important in the establishment of visibility, and is governed by the colors of the light produced by the source. Incandescent and fluorescent bulbs have the best color rendition, while uncoated mercury vapor and low-pressure sodium have the worst, emitting light in a very narrow spectral range. Somewhat between these extremes lies high-pressure sodium, which emits a yellow-white colored light. There is still some controversy over how to assess the color-rendering properties of HID sources. This issue is dealt with in the subsection on system measurement.

Finally, the luminaire (i.e., the unit which contains and protects the lamp) is designed to focus and reflect the light so that the desired light distribution pattern occurs. In addition to the indicated light distribution in the horizontal roadway plane, one can also consider the distribution of light in a vertical plane. Luminaires are also classified as "full-cutoff," "semi-cutoff" or "non-cutoff," to indicate the degree to which the lamp's glare is shielded from an observer; full-cutoff being the most shielded. The cutoff feature is important for visibility, since the glare from a luminaire can produce attention conflicts between the luminaire and other elements in the field of vision, due to the phototropic, or light-seeking, reflex of the human eye [A.3-64].

In sum, given the desired performance specifications, it is the lighting engineer's task to choose a configuration of all of the street lighting components in Exhibit 2.6 which will meet those specifications.

SYSTEM DESIGN

The design of a street lighting system is usually guided by the available standards on street lighting and constrained by the limitations of equipment manufacturers and local utility companies. Unfortunately, the existing street lighting standards are lacking in several respects, especially in pedestrian-oriented emphasis, and the heavy reliance on industry may be detrimental in the long-run.

Existing Street Lighting Standards Are Lacking

Technical standards for the performance of street lighting systems in the United States are put forward by the American National Standards Institute (ANSI), under the sponsorship of the Illuminating Engineering Society (IES) of North America [A.2-59]. IES has developed and amended these standards, known as "American National Standard Practice for Roadway Lighting," since 1925, and has specifically designated its Roadway Lighting Committee as the group responsible for updating the standards to reflect changes in knowledge and technology. The other organization involved in setting standards for street lighting systems is the International Commission on Illumination (CIE, which are the initials of its French designation, Commission Internationale de l'Eclairage). CIE publishes international recommendations to serve as a basis for the drafting of uniform national codes among participating countries. As such, it is not a binding professional standard, but it does represent another view on the desired characteristics of street lighting systems.

Exhibit 2.9 compares the IES and CIE standards: it is seen that there are similarities as well as significant differences between their recommendations. For example, the IES standard for the amount of light is based on *illumination* of the horizontal roadway or walkway surface (i.e., amount of light *falling onto* the surface) while the comparable CIE recommendation is made for the road surface *luminance* (i.e., amount of light *reflected from* the surface). Similarly, the recommendations on uniformity of the light distribution

Exhibit 2.9

Existing Street Lighting Standards

Measure	Nature of Standards: Illuminating Engineering Society (IES)	Nature of Standards: International Commission on Illumination (CIE)
Horizontal road or walkway surface illumination	Recommended minimum	Not addressed
Road surface luminance (brightness)	Addressed qualitatively in conjunction with other factors	Recommended minimum
Ratio of average to minimum illumination	Maxima given as guidelines (to be considered with other factors)	Not addressed
Ratio of average to minimum luminance (brightness)	Not addressed	Recommended maximum
Glare	Addressed qualitatively in conjunction with other factors	Recommended maximum level
Road classification	Indirectly addressed through classification of recommendations, including recommendations for pedestrian walkways	Indirectly addressed through classification of recommendations. Pedestrian walkways treated in separate document
Land use	Indirectly addressed through classification of recommendations	Not addressed
Brightness of "Surround"[1]	Included under "Glare"	Indirectly addressed through classification of recommendations
Visual guidance[2]	Not addressed	Guidelines given
Optical guidance[3]	Not addressed	Guidelines given
Other measures (luminaire type, mounting height, spacing and arrangement, traffic conflict areas, border areas, transition lighting, and alleys)	Guidelines given (to be considered with other factors)	Not addressed

Sources: [A.2-59, A.2-62].

[1] The "surround" is defined by lighting engineers as a specific area immediately surrounding a visual task.

[2] "Visual guidance" increases the visibility of the road against the surrounding environment.

[3] "Optical guidance" provides detection from a distance of roadway curves, intersections and other singularities.

deal with illumination and luminance, respectively. Although IES and CIE both recommend different light levels for different types of street (e.g., arterial versus local residential), they differ in the definition and classification of streets. The IES includes pedestrian walkways as well as diverse land use in its classification, while the CIE focuses on the brightness of the "surround" and treats pedestrian walkways separately. The CIE also gives quantitative recommendations for the limitation of glare, while the IES gives overall guidelines to minimize glare in conjunction with a variety of other factors.

The existing street lighting standards are lacking in several respects. First, the standards place a greater emphasis on vehicular roadways than on pedestrian walkways. Consequently, it is not surprising to see that the designers of street lighting projects, *even* crime-related projects, are concerned more with roadway lighting than with walkway lighting. For example, in comparison with the IES specifications in Exhibit 2.10, Exhibit 2.11 shows that the performance specifications* of the Study Sample projects generally meet or exceed the IES specifications for roadways, but are usually not even explicitly stated for walkways. It is also interesting to note that of the nine LEAA-funded projects which gave information on specifications, only one--the street lighting project in Denver, Colorado--addresses pedestrian walkway illumination and uniformity. One reason for this lopsided

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*It is to be noted that "performance specifications" reflect the *desired* performance of the system--as identified in the project plan--and do not necessarily reflect the actual performance of the implemented system.

Exhibit 2.10

IES Standards: Horizontal Illumination Specifications

Roadway/Walkway Classification	Area Classification: Commercial		Intermediate		Residential	
	Illumination (footcandles)	Uniformity Ratio[1]	Illumination (footcandles)	Uniformity Ratio[1]	Illumination (footcandles)	Uniformity Ratio[1]
Vehicular Roadways						
Freeway	0.6	3:1	0.6	3:1	0.6	3:1
Major	2.0	3:1	1.4	3:1	1.0	3:1
Collector	1.2	3:1	0.9	3:1	0.6	3:1
Local	0.9	3:1	0.6	3:1	0.4	6:1
Alleys	0.6	3:1	0.4	3:1	0.2	3:1
Pedestrian Walkways						
Sidewalks	0.9	4:1	0.6	4:1	0.2	10:1
Pedestrian Ways	2.0	4:1	1.0	4:1	0.5	10:1

Source: [A.2-59]

[1] Ratio of average to minimum horizontal illumination.

Exhibit 2.11

Street Lighting Projects: Performance Specifications

Project Performance Specifications:	Number of Projects			
	Vehicular Roadways		Pedestrian Walkways	
	Horizontal Illumination	Uniformity Ratio	Horizontal Illumination	Uniformity Ratio
Exceed IES	19	13	5	4
Meet IES	7	10	0	0
Do Not Meet IES	2	1	0	0
Not Specified[1]	1	2	19	20
No Information[2]	12	15	17	17
Total	41	41	41	41

[1] "Not Specified" implies that project designer(s) felt that there is no need to specify.

[2] "No Information" implies that the specifications, if they exist, were not identified in the course of the Study Sample interviews.

emphasis is that since the advent of the automobile, traffic safety has been on the minds of engineers and city planners much more than pedestrian security. Another reason is that project designers generally *assume* that if roadway specifications are met, then walkway specifications would automatically be satisfied. The assumption is not necessarily true.

A second problem with existing street lighting standards is their reliance on the horizontal illumination as a key measure. It has been hypothesized that such characteristics as vertical illumination, color rendition, contrast and visibility--on both the walkway and the roadway--are more relevant to crime prevention than horizontal illumination [A.2-74, A.2-83, A.2-89, A.3-22, A.3-64]. In fact, recent experiments suggest that horizontal roadway illumination is a good predictor neither of visibility nor of traffic safety [A.2-36, A.2-66]. Horizontal illumination has been popular primarily because it is easy both to design for and to measure [A.3-106].

Finally, a third problem is inherent in the fact that the standards are primarily based on expert opinion rather than scientific research. However, as new scientific evidence becomes available, the standards are being updated. For example, the IES is planning to issue a revised set of standards sometime this year. Nevertheless, the existence of pedestrian walkway standards does not imply an understanding of *how* street lighting affects pedestrian security (i.e., crime) or the sense of security (i.e., fear of crime). On the contrary, as is discussed in Section 4, none of the existing studies in street lighting has even begun to address this complex issue. It does not, however, mean that no standards should be promulgated just because an understanding of the underlying theory is missing. In fact, if it can be *assumed* that street lighting affects crime, then *pedestrian-oriented* standards should be determined, and they should be integrated with roadway-oriented standards. Section 6.1 argues that one can assume that street lighting affects the *fear of crime*, so that the pertinent standards should be determined. Section 6.3 outlines a research activity that should provide the necessary information for such a determination.

Heavy Reliance on Industry

Industry (i.e., equipment manufacturers and utility companies) plays a pivotal role in the design of a street lighting system. Whatever the design may be, it is most likely based upon standards, such as those promulgated by the IES, which have been developed with industry support; it must use equipment that is readily available and stocked by manufacturers; and it must conform to the guidelines established by the local utility company. The willingness of manufacturers and utility companies to invest research,development or inventory resources in, say, innovative, pedestrian-oriented hardware is, rightly, dependent upon the industry's perception of the potential market. Therefore, a heavy reliance on industry to provide objective guidance and support is not only infeasible but unrealistic in the *long-run*.

Until recently, there has been little demand for pedestrian-oriented street lighting by municipalities. In fact, industry has been pushing for innovation. Considerable efforts have been made by representatives of manufacturing and utility companies to promote decisions in favor of increased and improved street lighting [A.1-22, A.1-23, A.2-44, A.2-67, A.2-88, A.2-92]. These efforts include dissemination of statistics relating street lights to reduced crime and traffic accidents, and preparation of promotional material on the effectiveness of the high-pressure sodium lamp as a "crime-fighter" because of its distinct yellow color, which could be a warning to the users of the area. Although the activities of the most prominent of the industry groups--the Street and Highway Safety Lighting Bureau--ceased several years ago, they have provided a stimulus for such community crime prevention efforts as "Light the Night" and "To Stop a Thief, Light a Light." The emphasis on high-pressure sodium has, however, resulted in some adverse effects. In several high-crime communities, the local residents welcomed improved lighting but were against the installation of high-pressure sodium; they did not want to be stigmatized as a high-crime community by the "yellow light." For the same reason, the Mayors of at least two cities--Newark and New Orleans--rejected street lighting designs which called for high-pressure sodium.

Some cases of innovation can be identified. In Philadelphia, for example, a manufacturer developed a special lamp--a 70 watt high-pressure sodium lamp--for use in low mounting heights, in residential areas that are heavily shaded by trees. The lamp provides the efficacy of high-pressure sodium without the glare that a higher-wattage source would have produced at the required mounting height. In other cases, problems were encountered when unusually low illumination levels or totally new hardware, including wiring, poles and luminaires, were introduced into small target areas. In most instances, equipment costs were extremely high, and, in one instance, the utility company was reluctant to stock items that would only be used in small numbers.

The major laboratories where innovations in street lighting are being fostered, are for the most part attached to the established giants in the industry. Some independent research is being carried out by the Illuminating Engineering Research Institute (IERI), a non-profit entity, which conducts basic research into such fundamental problems as the development of instrumentation for measuring visibility. Presumably, however, its research agenda is in some sense responsive to the industrial interests which partially fund IERI through donations.

Despite the innovative steps taken by industry, a mechanism is required for aggregating and focussing the still diffuse demand for pedestrian-oriented street lighting innovations. Since the public is the ultimate consumer of street lighting products, the representation of the growing need for pedestrian-oriented lighting ought to be a public function. In the case of traffic safety, the U.S. Department of Transportation (DOT) has promoted, guided and funded research directed at traffic safety. The expansion, either through interagency cooperation or a broadened mandate, of the DOT-sponsored research to include crime-related, pedestrian concerns would (a) provide a mechanism for establishing a research agenda sensitive to the changing needs of the public in the areas of traffic safety and pedestrian security; (b) provide a rationale for public support of industrial laboratories, IERI, and other private consultants in their conduct of studies and projects which further the research agenda; and (c) stimulate industry support of innovations by better defining the need for innovation.

SYSTEM MEASUREMENT

As stated earlier, the performance specifications reflect the *desired* performance of the system--as identified in the project plan. The *actual* performance must be measured. Unfortunately, most projects do not have measurements made after the street lighting system is installed. Whatever light measurements are made, are very minimal; and cost measurement data are also lacking in specificity.

Light Measurements Are Minimal

Interviews with municipal officials indicate that light measurements are rarely made, usually only in a test installation. One reason is that it is time-consuming and somewhat expensive to make the necessary measurements. For example, in order to compute average illumination or uniformity ratio, it is necessary to make horizontal illumination measurements every ten feet along the center of each lane of, say, a roadway, and to record the condition of lamps and luminaires, the pole mounting height, the spacing and arrangement, the interference of environmental objects (e.g., foliage, fences, etc.), and the existence of extraneous light sources. It is therefore unrealistic to expect light measurements to be made unless the evaluation budget explicitly provides for them.

Another reason for the paucity of light measurements is the lack of instrumentation. A somewhat surprising fact emerged from the telephone interviews: very few municipalities actually own standard light meters that are in working condition. Likewise, the utility companies lack instrumentation and are just as reticent about making light measurements. The relevance and benefits of different light meters is also a topic of discussion and contributes to the measurement problem. For example, the accuracy of available color-corrected light meters is being questioned. It is common practice to measure illumination and luminance, and therefore all measures derived from them (e.g., uniformity, glare, visibility, etc.), using so-called "color-corrected" meters. These meters employ a filter whose light transmission properties, as a function of wavelength (i.e., color), vary in a way which approximates the response of the human eye to different wavelengths. The term *photometry* applies to such measures, in contrast to *radiometry* which includes measurements that weigh all wavelengths equally. The human eye is approximately five times as sensitive to green light as to violet or yellow light, when adapted to nighttime light levels (i.e., scotopic vision), and is five times as sensitive to yellow light as to blue or red light, when adapted to daytime levels (i.e., photopic vision) [A.2-26, p. 18]. The issue which has arisen is that, although the color-correcting filters are relatively accurate on the average over the whole spectrum, and therefore are suited to measurement of sources with continuous spectra, they may be inaccurate when used with line spectrum sources such as high-pressure sodium or mercury vapor. The problem stems from the fact that an error at one particular wavelength in the response of the "color-correcting" filter, relative to the human eye's response, would not be compensated by errors in the opposite direction, since all the light is concentrated at a few wavelengths [A.2-10, p. 150].

An alternative to direct measurement is *suggested* by recent experiments and by an extension of the common practice of many cities: that is, relying on the system design specifications to derive other relevant light measures. In some detailed designs, it is possible to estimate the average horizontal illumination and uniformity ratio. Using the same principles, it is also possible to develop computer-based mathematical models that could predict the light measures of interest [A.2-36, A.2-101, A.2-102]; these models must also be tested and calibrated with actual light measurements. Thus, a great deal of flexibility can be preserved if the initial work on model development can be continued and expanded. But the applicability of this work is dependent on the *availability* of detailed and complete descriptions of street lighting systems.

Cost Measurements Are Lacking

Project funds are used for many purposes, including system design, purchase and installation of equipment, leasing from a utility company, and purchase of electric power. Identifying the uses of project funds is not sufficient; cost measurements must not only include the cost figures but must also *relate* them to system characteristics. Most street lighting projects do not provide the necessary information to determine such cost measurements, in part because there are no standard measures for relating cost figures to system characteristics.

A popular approach has been to define measures which relate total annual cost to an appropriate unit of street lighting. The unit which has been used in some recent studies [A.2-20, A.2-66] is one mile of an equivalent *arterial* system (i.e., a system covering only a single lineal street pattern, as opposed to one covering every street in a given area*). Another unit has been an *effective lumen*. For illustrative purposes, Exhibit 2.12 summarizes the components of a total annual cost per effective lumen computation for two different light sources. The lamp characteristics (i.e., initial lamp lumens, lamp depreciation factor, dirt depreciation factor, and coefficient of utilization) which determine the effective lumen rating are usually specified by the manufacturer, while the calculation of total annual cost requires (a) the specification of initial cost, if any, to the city,** (b) its conversion to an amortized annual cost based on assumptions of the system's life span, the interest rate structure, and the value of capital recovery, and (c) the specification of all ongoing energy,

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* Translating an area-wide system into an equivalent arterial system requires some detailed calculations. It should be noted that, in general, an area-wide system requires fewer street lights than an equivalent arterial system because of the sharing of lights at street intersections in the area-wide system.

** In a utility-owned system, there may be no initial cost, or there may be a penalty charge for early termination of a lease.

Exhibit 2.12

Components of Total Annual Cost Per Effective Lumen

Component	250 Watt Mercury Vapor	150 Watt High-Pressure Sodium
Initial Lamp Lumens (i.e., total lumen output of a new lamp)	12,100	16,000
Lamp Depreciation Factor (i.e., correction for average decreased lamp output due to aging)	.81	.90
Dirt Depreciation Factor (i.e., correction for average decreased luminance efficiency due to dirt accumulation)	.85	.95
Coefficient of Utilization (i.e., fraction of luminaire output falling on roadway and walkway surfaces; a function of mounting height and pole spacing)	.75	.80
Effective Lumens (i.e., initial lamp lumens corrected for lamp and dirt depreciation and coefficient of utilization)	6,248	10,944
Initial Installation Cost	$859	$884
Annual Amortization	$127	$128
Annual Energy Cost[1]	$ 46	$ 29
Average Annual Maintenance[2]	$ 20	$ 23
Total Annual Cost	$193	$180
Total Annual Cost Per 1,000 Effective Lumens	$ 31	$ 16

Source: [A.3-78][3]

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[1] Includes ballast losses.

[2] Includes average materials and labor for cleaning and spot replacement.

[3] This exhibit is presented here for illustrative purposes only, and does not imply the authors' agreement with the stated figures, which were compiled by the indicated source.

maintenance, and, if appropriate, leasing expenses. However, if the system costs vary significantly over the life span of the system (e.g., energy cost has been increasing at a very fast rate), the validity of a calculated annual cost becomes questionable, and gives rise to a need for a *life-cycle* cost measure, which is defined as the sum of the present values of the *anticipated* annual costs over the entire life span of the system.

As in the case of the light measurements, cost measurements *can* also be derived using computer-based models, *provided* pertinent detailed data are collected. The models themselves are straightforward to develop and program, once the desired cost measurements are identified.

2.3 RELATED ISSUES

There are interactions between a street lighting system and its contiguous, larger environment which are relevant to a study of street lighting and crime. These interactions involve street lighting and its *energy* demand, its impact on certain *legal* issues, and its relationship with other *environmental* conditions and programs. Each one of these interactions may be viewed as placing *constraints* on the design and operation of a street lighting system. These constraints, in turn, cannot be ignored when evaluating the impact of street lighting on crime. The energy, legal and environmental issues are considered in more detail below.

ENERGY ISSUES

Since the energy shortage of 1973-1974, virtually every system which consumes energy has come under scrutiny for the identification of possible energy savings, and street lighting systems are no exception. In fact, this scrutiny is probably as much related to the *conspicuousness* of street lights as to the amount of energy consumed, since the energy required to maintain street lighting systems constitutes only *0.18 percent* of the total energy consumed in the United States* [A.2-42 (No. 100A)].

The focus on street lighting as an area for energy conservation can provide an opportunity for "natural experimentation" and has highlighted a need for a total systems approach to energy conservation.

Opportunity for "Natural Experimentation"

The question arises whether an energy conservation related reduction in street lighting (i.e., a "brown-out") by a community can provide an opportunity for retrospectively determining a change in the level of crime, attributable exclusively to the change in light level. In order for such a "natural experiment" to be successful, however, three questions would have to be answered: What is the duration of the experiment? Are there any concurrent, possibly energy-related, changes in such activities as police patrol? And are there any other energy-related changes in overall crime patterns?

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* An analysis of U.S. energy consumption reveals that approximately 75 percent of the energy is non-electrical in nature. Of the 25 percent electrical energy, 5 percent is required for lighting purposes. However, only 3.5 percent of all lighting energy goes to street lighting, resulting in an energy consumption equal to 0.18 percent of all U.S. energy.

Study Sample interviews reveal that in communities where the street lighting level was reduced in the 1973-1974 energy crisis, police and citizens were especially sensitive to the possible public safety and security consequences. As a result, local officials tended to place street lights high on their list of priorities for restoration to earlier energy use patterns, causing street light curtailments to be brief and limiting the amount of available data. This tendency is illustrated in Exhibit 2.13, along with the fact that the locations of street lighting reductions have mostly been in such places as free-ways, where the incidence of crime is not prevalent. Unfortunately, with the possible exception of New York City, it has not been possible to date to identify a municipality which curtailed its street lighting output long enough to accumulate statistically meaningful data, or in locations where crime is significantly measurable. Future reductions in street lighting could be longer lasting, and thus meet the first requirement of a natural experiment.

The second question, that of concurrent, possibly energy-related, changes in police patrol, is important in two respects. On the one hand, cutbacks in police patrols due to a shortage of available fuel could contribute to an increase in crime. On the other hand, some police departments may increase patrols in darkened areas, which would reduce their energy savings and intervene in the natural experiment. Although federal fuel allocation regulations during the recent energy crisis provided for law enforcement agencies to receive 100 percent of their accustomed consumption, actual allocations varied widely [A.2-78].

Exhibit 2.13

Energy-Related Reductions in Street Lighting

City	Action Taken	Reason for Reduction	Duration	Reason for Restoration	Crime Impact Measured?
Chatanooga, TN	Turn off all street lights on freeways	Set an example	2 months	Continued non-energy charges by utility company	No
Detroit, MI	Turn off alternate street lights and reduce burning hours in Central Business District (CBD)	Set an example	3 days	Citizen complaints	No
Knoxville, TN	Turn off all street lights on non-CBD freeways	Fulfill utility (Tennessee Valley Authority) request	4 months	End of energy shortage	No
New York, NY	Reduce lamp wattage; turn off alternate street lights on freeways and in "overlit" areas	Effect cost savings	Permanent	---	No
Wichita Falls, TX	Turn off all street lights on freeways and arterial median strips	Effect cost savings; set an example	8 months	Continued non-energy charges by utility company	No

Some police departments either had to curtail operations because of unavailability of fuel, or had to institute energy conservation practices for budgetary reasons, as the price of available fuel increased. Another factor that could have affected police operations was in connection with plans for "rolling blackouts"--a technique to lower total electrical energy consumption, without placing an enduring burden on any one segment of a community. Under this technique, various areas of the city are disconnected from electrical service for two to three hours on a somewhat random basis and with about a 24-hour notice. Existing federal guidelines for law enforcement agencies recommend the preparation of strategies involving additional personnel for patrols and traffic direction [A.2-80]. Despite the existence of plans for rolling blackouts, the authors are unaware of any that has actually been implemented. Yet, these plans do reflect law enforcement officials' awareness of the need for extra activity during a period of reduced street lighting. As a result, any retrospective analysis of natural experiments would have to be able to take police patrol activity changes into account.

The third question, that of energy-related changes in overall crime patterns, arises out of the fact that some, previously law-abiding, individuals could be severely impacted, both economically and physically, by an energy shortage and violent crimes are one possible expression of the resulting frustration [A.2-81]. Similarly, a sudden, total blackout could lead to unique circumstances which impair the integrity of a natural experiment. Eliminating electricity entirely and abruptly is a massive intervention, affecting the basic structure of a community and interrupting both street lighting and other essential services, as well as comforts and conveniences, such as televisions and air conditioners. Thus, the July, 1977 blackout in New York City cannot be thought of as a natural experiment; the extended looting of neighborhood stores was not only a result of the opportunities occasioned by the sudden blackout, but, as Andrew Young, the U.S. Ambassador to the United Nations, said, also a result of the deep-seated frustration which plagues the poor.

In summary, although it may be possible in the future to identify localities where crime trends during a period of reduced street lighting can be observed retrospectively in a natural experimentation sense, such an evaluation would have to take into account the duration and location of the experiment, the changes in police patrol, and the independent, energy-related changes in crime patterns.

Need for a Total Systems Approach

An examination of the responses of municipalities and the lighting industry to demands for street lighting energy conservation shows that the solutions chosen by many municipalities have a direct influence on street lighting design. As indicated in Exhibit 2.14, the earliest and simplest energy conservation recommendation--that of reducing illumination--has in time given way to the use of more energy-efficient light sources, especially high-pressure sodium which, as shown in Exhibit 2.8, produces more than twice the lumens per watt as mercury

Exhibit 2.14

Some Energy Conservation Recommendations for Street Lighting

Date	Source	Recommendations
12/72	Illuminating Engineering Society	• Design lighting pattern for expected activity • Use more effective and efficient luminaires • Use efficient light sources • Select luminaires with good cleaning capability and lamps with good lumen maintenance • Provide flexible switching and dimming controls
12/73	Federal Energy Office (Fact Sheet on National Energy Conservation)	• Reduce indoor illumination levels by approximately 50% in commercial and industrial buildings
3/74	Law Enforcement Assistance Administration (Energy Report No. 2)	• Reduce street lighting energy use only under following conditions: - as part of a comprehensive community conservation program - after review of sensitivity of crime to street lights, with police and citizen representatives - after exploring alternative more efficient light sources
4/74	Federal Energy Office (Decreased Illumination of Highways: Guideline)	• Reduce highway lighting energy requirements by 50% • Retrofit with more efficient light sources • Maintain IES-recommended illumination levels as maxima • Reduce illumination in proportion to daily traffic density variation, while maintaining IES-recommended uniformity ratio
5/74	Federal Highway Administration (Letter re: lighting on federal-aid highways)	• Maintain IES-recommended illumination levels and uniformity ratios
11/74	Federal Energy Administration (Lighting and Thermal Operations Guidelines: Energy Management Action Program)	• Encourage efficient lighting practices • Recognize that complexity of scientific, management, engineering and architectural components limits applicability of simple guidelines • Maintain previous indoor illumination standards as maxima • Convert to more efficient sources • Practice periodic cleaning and maintenance
12/74	Federal Highway Administration (FHA Guidelines)	• Maintain previously recommended illumination levels and uniformity ratios
6/75	International Committee on Illumination	• Design for required tasks and needs of user population • Maintain recommended light levels • Select most efficient lamps, taking into consideration color rendering needs • Select efficient luminaires • Provide flexible switching and dimming controls • Establish adequate cleaning and maintenance program

Sources: [A.2-4, A.2-42 (Nos. 120, 122, 123, 129 and 130), A.2-62, A.2-69 and A.2-79] vapor and five times as much as incandescent. What is needed, however, is a total *systems approach* to the design of street lighting systems that are at once energy- and cost-efficient.

To date, the principal energy conservation approach has been to reduce illumination by (a) turning out alternate bulbs; (b) turning out all (or some) bulbs after certain hours; (c) reducing wattage by rewiring or employing dimmer transformers; or (d) replacing higher-wattage lamps with lower-wattage lamps of the same type. More recently, the approach has been to increase source efficacy by replacing existing lamps with high-pressure sodium lamps. Resistance to this approach has, however, persisted, based on uncertainty as to the net *economic* benefit of conversion, coupled with objections to the color-rendering properties of high-pressure sodium and a perception of stigma associated with earlier use of this source in high-crime areas [A.3-9, A.3-24, A.3-114, A.3-127]. Thus, a complex set of tradeoffs, both quantitative and subjective, is required for the design of cost-effective street lighting systems, involving many more parameters than the simple notion of source efficacy.

Both the IES and the CIE recommendations in Exhibit 2.14 *point* to an energy conservation approach that is based on total system design, but the approach *remains* to be defined. The refinement of light and cost measurements would contribute to such a definition. As an illustration of how the total systems approach can lead to design solutions which defy "conventional widsom," a street lighting project in Norfolk, Virginia [A.1-59] is briefly discussed here. In this project, a street lighting system in the Ghent inner-city residential neighborhood of Norfolk was relit with a design developed to differentiate street types, pedestrian paths and intersections in a clear visual hierarchy. One aspect of the design was the use in residential streets of low-intensity lamps mounted on closely spaced and relatively low poles, using colonial-style luminaires, compatible with neighborhood characteristics. The objective was to foster a greater sense of security and to encourage night street use by having aesthetically pleasing incandescent sources, greater illumination uniformity, and better and more fixtures. The design as described above resulted in cost and illumination levels ower than what would have been obtained with mercury vapor or high-pressure sodium sources. The very high level of satisfaction demonstrated by a user survey after the completion of the project suggests that, if other design objectives can be met better by having low-efficacy sources (e.g., incandescent), total energy consumption may be minimized without necessarily using the brightest or most efficient light sources.

LEGAL ISSUES

The law is becoming increasingly involved in two areas of street lighting. First, the establishment of local building security ordinances, which extend the concept of building codes to include property owners' obligations to take basic security-oriented steps, including lighting, and, secondly, the possible civil liability of individuals or municipalities for damages incurred as a result of criminal activity following reductions in outdoor lighting.

Building Security Ordinances

Based on the premise that physical planning can reduce criminal opportunity, some municipalities have introduced ordinances requiring design or performance standards to be met by property owners to facilitate crime prevention. The LEAA has awarded funds through both its block action and discretionary grant programs for the design of secure public areas, and many of these awards include the drafting of model building security ordinances.

To the extent that such ordinances require some sort of indoor or outdoor lighting, they result in effects on the overall design of the environment, often setting standards to limit intrusion onto contiguous properties [A.3-78]. Because they impose a cost burden on private property owners, their passage is likely to become a heated political issue. As with all regulatory activities, the monitoring of building security code compliance would also entail a certain amount of public expense and commitment.

Within the Study Sample, five cities reported knowledge of ordinances requiring private lighting: in four, the ordinances covered parking lots; in three, building interiors (i.e., hallways, elevators and stairways) were covered; and in one, exterior lighting was required. Wherever local ordinances have an impact on the boundaries of the lighted environment, evaluations of street lighting and crime will have to take this into account.

Possible Civil Liability

Municipal officials are sensitive to the possible crime-related liability of cities which curtail street lighting output. This sensitivity and sense of obligation have limited the application of energy-conserving illumination reductions in a number of cities.

At the present time, no cases are known in which municipalities have actually been found *guilty* of negligence for reducing street lighting, but a search of cases reveals several in which a city or property owner may incur liability in other lighting-related situations [A.3-103]. The City of Chicago Heights, Illinois, for example, was held liable for injuries sustained by a motorist at an intersection with an improperly placed and glaring street light. The court did not, however, review the city's estimate of public needs, its discretion in selecting a plan, or its inherent legislative powers. Only the positive action which created a dangerous condition was considered [13 ATLA News L. 111-12 (1970)]. In another case, the City of Los Angeles was found liable for injuries sustained by a plaintiff who fell after the parking lot lights were suddenly extinguished [11 ATLA News L. 411 (1968)].

Private property owners have also been held liable for injuries and criminal attacks sustained by employees, church members, tenants and customers as a result of missing or defective lighting. In one of these cases, the widow of a police officer, who was killed while patrolling the rear of a store at which the owner had turned off the outside lights, successfully sued the store owner for negligence imperiling the safety of an invitee [Fancil vs. Q.S.E. Foods, Inc. 311 N.E. 2d 745 (Ill, App. 1974)]. Testimony in the trial of this case

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1 OF 4

included an amici curiae (friends of the court) brief filed by the Americans for Effective Law Enforcement, Inc., the Illinois Association of Chiefs of Police, and the Illinois Police Association. It is interesting to note that the brief cited two studies which concluded that street lighting improvements can reduce commercial burglaries and assaults that are committed on commercial properties [A.2-25]. This situation underlines the *need* for accuracy and methodological rigor when reporting on the crime prevention effects of street lights. One of the studies cited in the brief shows no evidence of having addressed the issues of randomization, control sites, and tests of significance [A.2-68, p. 10]. The other study, the Kansas City street lighting study [A.1-30], does deal with these issues, but as discussed in Section 4.3, the significance of the reported impacts is questionable, because of the likelihood of regression artifacts and the failure to consider the impact of a significant increase in police manpower and of a concurrent police patrol experiment.

Another interesting legal issue concerns the possibility of citizen suits against municipalities for failure to deliver equal street lighting services in different neighborhoods within the same taxing jurisdiction. It is not unlikely that, with the dismantling of neighborhood advocacy programs, such as Model Cities, this issue will emerge from the bureaucratic process into the legal process, in much the same way that the movement for equal housing rights has evolved.

ENVIRONMENTAL ISSUES

A street lighting project is part of a larger environment, and it must be viewed from this broader perspective. In the design of a street lighting project, it is important to consider (a) the impact that the project would have on its environment; (b) the impact that other concurrent programs (i.e., law enforcement, physical, and social programs) would have on the project; and (c) the degree to which the project contributes to a broader synergistic program (i.e., the Crime Prevention Through Environmental Design--CPTED--Program).

Need to Assess Environmental Impact

During the planning stage of a street lighting project, failure to consider its possible impact on the natural environment or on historically significant neighborhoods can lead to delays, lack of public support, design changes and/or cost inflation.

One problem which has threatened to constrain street lighting designs is the potential harmful impact of street lighting on trees and shrubs. Experiments performed at the U.S. Department of Agriculture's Agricultural Research Center (ARC) in Beltsville, Maryland suggested that street lights can increase the growth rate of a plant, which in turn increases its susceptibility to air pollution, delays its onset of dormancy in autumn, and increases its likelihood of succumbing to early frosts [A.1-27, A.2-1, A.2-95, A.2-109].

The above-mentioned effects were studied under controlled conditions over a two-year period using five different light sources on seedlings of twenty-two species of trees and other plants [A.2-95].

Among the results was the fact that the effects on growth, pollution sensitivity and dormancy are most acute for incandescent and high-pressure sodium lamps. As a result, some municipal officials indicated that if definite evidence of tree damage could be proven, they would replace high-pressure sodium lights with mercury vapor or incandescent lights [A.1-17, A.1-68]. New York City, for example, announced plans to coordinate street and park light installation with the selection of more resistant tree varieties, and with scheduling plantings during dormant periods [A.2-110].

After the initial concern, subsequent analysis of field reports and clarifying remarks by the Beltsville ARC have suggested that the effects are not harmful to mature trees and are generally less detrimental than other environmental hazards [A.2-1, A.2-109]. Additionally, Study Sample interviews indicate that, although knowledge of this environmental problem is widespread, the consensus is that the problem is not serious enough to deter the use of high-pressure sodium lights.

On the other hand, the need to consider the architectural character of the surrounding neighborhood does not appear to be diminishing. The need is obvious in those neighborhoods which are formally designated as historical areas. Actual opposition to street lighting projects has developed only rarely, but when it has, the consequences have included litigation, delays, adverse publicity, cancellation of improvements in portions of the target area, and requirements to redesign luminaires [A.2-67, A.3-4, A.3-47, A.3-128].

Need to Assess Concurrent Programs

Of the 41 Study Sample projects, 29 reported the presence of concurrent programs in law enforcement, physical improvements or social services, all of which could potentially *affect* an evaluation of the impact of street lighting on crime.

Seventeen projects took place with concurrent law enforcement efforts, which included IMPACT Cities programs, police patrol experiments, citizens' crime prevention programs, and increases in the level of police patrol and drug enforcement. These efforts are of significance to street lighting and crime evaluations in three ways. First, and most obviously, other law enforcement efforts could directly reduce the amount of crime. Second, they could change the *level* of crime reporting. Third, as detailed in the next subsection, there could be a synergistic effect, in which the combined effect of a street lighting project and another program, such as a law enforcement program, is greater than the sum of the effects of each acting alone.

Physical improvements, other than target area street lighting, were present in 18 projects, and included central business district revitalization, city-wide or adjacent area street lighting, urban renewal, demolition of buildings, housing construction or rehabilitation, tree pruning, street furnishings and signs, and Community Development projects. In many of these cases, the street lighting project was an integral part of a larger program, so that there also exists the possibility of a synergistic effect.

Finally, concurrent social service programs took place in eight projects, consisting mostly of employment, youth, Model Cities and

Community Development programs. One of the impacts often claimed by these programs is a reduction in the *motivation* to commit crimes.

Need to Assess Synergistic Effects

The preceding subsection is not meant to imply that street lighting projects *ought* to be implemented in isolation from other crime-related efforts. In fact, the LEAA-supported, Crime Prevention Through Environmental Design (CPTED) program aims at preventing crime through a coordination and focusing of a number of different efforts.

In brief, the CPTED approach is based on the hypothesis that the *proper design and effective* use of the built environment can lead to a reduction in crime and fear, and, concomitantly, to an improvement in the quality of urban life [A.2-114]. Although the purpose of proper design of the built environment is to indirectly elicit the desired human behavior pattern and the effective use of the built environment represents a direct influence on human behavior, it is the combination of proper design *and* effective use that symbolizes the strength of the CPTED approach, leading to a synergistic outcome, where the combination is more effective than the sum of its parts. In terms of street lighting, it might be stated that improved street lighting alone (representing a design strategy) is ineffective against crime without the conscious and active support of both citizens (in reporting what they see) and police (in responding and conducting surveillance). In sum, CPTED encompasses those strategies--whether they be law enforcement, physical, or social in nature--that affect, either directly or indirectly, human behavior with respect to the built environment.

Four design concepts have been noted within CPTED [A.2-114, Section 3.3]:

(1) access control, which is primarily directed at decreasing crime opportunity and operates to keep unauthorized persons out of a particular locale;

(2) surveillance, which aims at increasing the risk to offenders and consists basically of keeping potential offenders under observation;

(3) activity support, which involves methods of reinforcing existing or new community activities as a means of making effective use of the built environment;

(4) motivation reinforcement, which, in contrast to the more mechanical concepts of access control and surveillance, is a correctional concept that seeks not only to affect offender behavior but also offender motivation--similarly, it seeks to elicit positive, motivation-based behavior on the part of the non-offender community.

Depending on the environmental mode(s) of concern to a CPTED program (e.g., residential, commercial, school, transportation, etc.), design concepts are integrated into a design strategy, leading ultimately to design directives and the creation or installation of relevant design elements.

Although CPTED has not been proven to be an effective crime prevention approach, the CPTED *process* is a powerful tool for conceptualizing and implementing environmental interventions to attain desired goals. As with any systematic approach, the usefulness of individual applications (e.g., street lighting), depends on the goal statement and on how carefully tradeoffs are made between conflicting goals.

Since street lighting is a key element in the CPTED approach, an evaluation of the impact of street lighting on crime will also significantly enhance the CPTED state of knowledge. The technical problem of evaluating street lighting as part of a broader synergistic program is considered in Section 3.1.

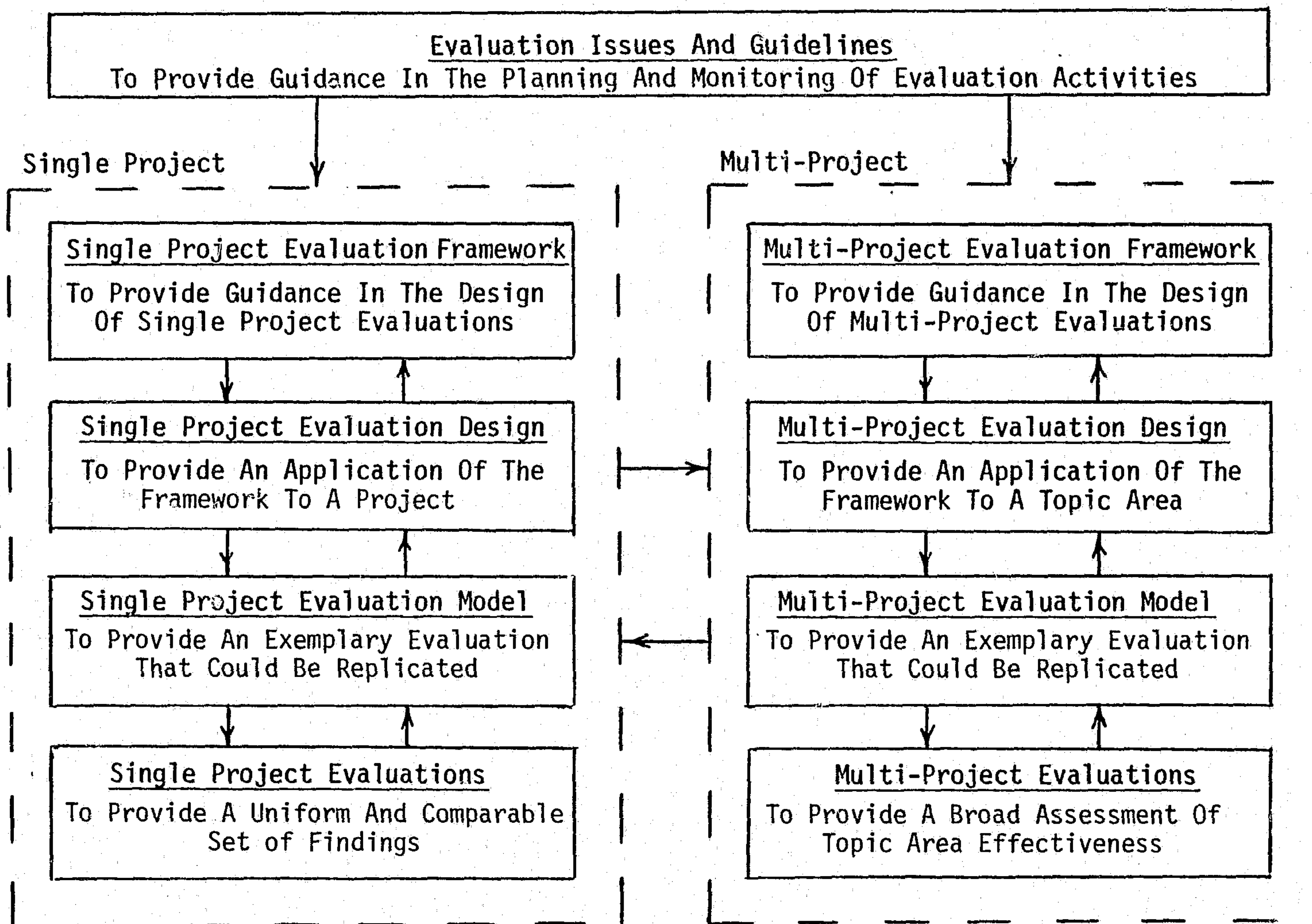
3 PHASE I EVALUATION FRAMEWORK

An NEP Phase I evaluation is an assessment of past and on-going projects in a defined topic area; in this respect, it is a *multi-project* evaluation. The Phase I or multi-project evaluation framework and the single project evaluation design that are outlined in this section and Section 5, respectively, can be regarded as two *steps* in the evaluation process.

As illustrated in Exhibit 3.1, an understanding of both the evaluation issues--see the discussion in Section 3.1--and the evaluation guidelines--see, for example references [A.2-121, A.2-122]--provides general guidance in the planning and monitoring of evaluation activities. In terms of both single project and multi-project evaluations, the required steps are the same. First, a *framework* is developed to provide specific guidance in the *design* of evaluation; that is, the framework is a focussed approach which insures the *relevance* of the evaluation results, especially to practitioners and policy-makers. In this section, a *dynamic roll-back* approach is proposed. Second, the evaluation design is an application of the respective framework to a project, in the single project case, and to a topic area, in the multi-project case. Third, the identification of an exemplary application of the evaluation design would enhance the widespread use of it, since potential users would be provided with a *model* example of *how to* undertake specific evaluations. The model evaluations could be identified and promulgated in much the same way as the LEAA is currently identifying and promulgating "exemplary projects." The fourth and final step is to

Exhibit 3.1

Evaluation Process



conduct a number of single project evaluations which would provide a *uniform* and *comparable* set of findings; these findings would, in turn, provide a basis for the multi-project evaluations, resulting in a broad assessment of the effectiveness of the topic area projects. It should be noted that, as experience is gained at any given step, feedback can take place to refine the previous steps; this is also indicated in Exhibit 3.1. Thus, for example, the identification of a single project evaluation model, based on the findings of several actual evaluations, could result in a series of improvements to both the design and the framework, and all of this activity would, in turn, provide the basis for updating the evaluation guidelines. In sum, Exhibit 3.1 identifies a process whereby the results of evaluation would be significant, pertinent and policy relevant. Indeed, if the process had been followed for the last decade, the NEP Phase I efforts would have been easier to undertake.

What is not clearly indicated in Exhibit 3.1, is the relationship between the single project and the multi-project evaluation steps. In general, it could be stated that at each step the single project consideration is subsumed under the multi-project consideration. Thus, for example, the single project evaluation framework is shown in Exhibit 3.2 to be a part of the multi-project evaluation framework.

Exhibit 3.2 also details the subject matter of this section: the single project and multi-project evaluation frameworks are considered in Sections 3.2 and 3.3, respectively. First, however,

Exhibit 3.2

Evaluation Frameworks: A Dynamic Roll-Back Approach

Multi-Project Evaluation Framework

Single Project Evaluation Framework

Evaluation Issues

- Are the existing evaluation measures *adequate*?
- Are the existing analytic techniques *adequate*?
- What are possible *methodological problems*?
- Is the proposed evaluation design *cost-effective*?

Evaluation Components

- Which are the *test hypotheses*?
- What is the *randomization/control scheme*?
- What is the *measures framework* in terms of the *explanatory* (i.e., input and process) and *impact* (i.e., attitude, behavior, and crime) measures?
- What are the *measurement methods*?
- What are the *analytic techniques*?
- What are the *data collection* (i.e., records, surveys, and observations), *data processing* (i.e., verification and analyses) and *impact analysis* (i.e., results and interpretations) procedures?

Evaluation Requirements

- What is the *project rationale* (i.e., objectives, hypotheses, and assumptions)?
- Who has *project responsibility* (i.e., principal participants and participant roles)?
- What is the nature of *project funding* (i.e., sources and uses)?
- What are the *project constraints* (i.e., technological, political, environmental, legal and cost/energy)?
- What is the content of the *project plan* (i.e., performance specifications, system design, and target area)?
- What is the nature of *project installation* (i.e., design verification and installation cost)?
- What is the nature of *project operation* (i.e., system output, system maintenance, and operating cost)?
- Are there any *concurrent programs* (i.e., law enforcement, physical and social)?
- What are the *anticipated evaluation findings*?

Multi-project level

- Evaluation Issues: Are the project data *uniform*?
- Evaluation Components: What is the *project typology*?
- Evaluation Requirements: Do projects belong to defined *topic area*?

some pertinent evaluation issues are discussed.

3.1 EVALUATION ISSUES

Like the street lighting issues in Section 2, the evaluation issues help to set the study of street lighting and crime in *proper perspective*. It is against this perspective that Section 6.1 assesses the current state of knowledge.

The answers to the five issue-related questions in Exhibit 3.2 (i.e., Are the existing evaluation measures adequate? Are the existing analytic techniques adequate? What are possible methodological problems? Is the proposed evaluation design cost-effective? Are the project data uniform?) are stated and elaborated on in the next five subsections, respectively.

EXISTING EVALUATION MEASURES

The existing evaluation measures are inadequate. At the present time, the explanatory measures characterizing light and the impact measures characterizing attitude, behavior, and crime are all inadequately defined, so that the evaluations, including street lighting evaluations, which are based on one or more of these measures can be *expected* to be somewhat inadequate. Indeed, some evaluations recognize the weaknesses in the existing evaluation measures.

Light Measures Are Inadequate

The standard light measures discussed in Appendix B are, of course, well-defined indicators of a street lighting system's performance, even though, as stated in Section 2.2, light measurements are seldom made. It is not clear, however, which light measures

should be recorded for the purpose of relating light to crime. Horizontal illumination level, taken at enough points on the road and sidewalk surfaces, provides a means of comparing system performance with the IES standards. Yet, a number of experts [A.3-22, A.3-64, A.3-106] have suggested that other light measures--such as vertical illumination, color rendition, contrast, glare, and road surface luminance--may be more relevant to street lighting evaluations than horizontal illumination.

In sum, there has been no extensive research aimed at defining those attributes of light which contribute to an individual's perception of crime or fear. The street lighting and crime evaluations which have been undertaken and which are reviewed in Section 4, have treated the subject matter on a macroscopic level and, moreover, have been based on such nondescript light measures as "relit" and "non-relit." In Section 6.3, it is recommended that a research activity be undertaken to address the relationship between light and perception of personal security; this microscopic level of research parallels current efforts in visibility analysis which has found increasing utility in the study of traffic safety [A.2-8, A.2-66].

Attitude Measures Are Inadequate

In terms of impact, street lighting may be justified as much for causing a reduction in the fear of crime as for reducing crime itself. Additionally, attitudinal changes brought about by street lighting can also cause changes in crime incidence. Unfortunately, attitude measures in general, and fear measures in particular, are in need of better definition, testing and refinement.

The National Crime Panel of the LEAA has attempted to include measures of the fear of crime in its victimization surveys, but the results have never been published, owing to the Panel's lack of confidence in their validity. The problem stems from the inability to ask the fear question in an explicit manner: "fear" is a term that brings out different feelings in different persons. The alternative approach has been to use various proxies for the fear of crime, such as how the respondent perceives the change in light quantity or quality. The problem, however, remains since there is still a need to relate the proxy measures to fear itself.

Attitudinal studies are being used with increasing frequency as a source of user feedback. User-oriented studies presently being funded by the U.S. Department of Housing and Urban Development and the U.S. Department of Health, Education and Welfare are likely to generate methodological contributions relevant to the evaluation of street lighting and crime.

Specific techniques which have been used in laboratory studies of the effect of light on attitude include the use of semantic differential rating scales for factor analysis and multidimensional scaling [A.2-32, A.2-71]. While these techniques have not had widespread application in outdoor nighttime environments, they appear to have potential applicability to the study of the impact of street lighting on human attitude and behavior.

Behavior Measures Are Inadequate

Measures characterizing behavior include respondent's reported use of the streets at night and level of nighttime business activity.

Like attitude measures, behavior measures require further definition, testing and refinement. However, behavior measures are easier to define than attitude measures, since the former set of measures reflect explicit actions rather than implicit attitudinal feelings. It is, of course, difficult at times to delineate between an attitude or a behavior, especially since one could impact or cause the other.

Reactions to street lighting have been quite varied. For example, one individual claims that high-pressure sodium lights produce adverse psychological effects, which cause headaches, disorientation, depression and suicidal tendencies [A.2-96]. On the other hand, those same lights have been claimed to be the cause of positive behavior patterns [A.2-42]. The question arises, therefore, whether any systematic studies have been performed which can help to clarify this issue: Are there fundamental human reactions to the way the environment is lit?

A review of the literature in the field of environmental psychology reveals that studies, which are concerned with the impact of light on human behavior, are quite limited, and are generally restricted to the observation of automobile driver performance [A.2-5, A.2-29, A.2-65]. Those studies suggest that behavioral traits such as territoriality, dominance, space and contact behavior, crowding, orientation and communal behavior may be affected by the spatial delineation provided by lighting.

The impact of an intervention, especially a mechanical intervention like street lighting, on criminal behavior is very difficult to ascertain. The intervention could either deter the potential criminal or offender from committing a crime altogether or cause a crime displacement. It has been hypothesized [A.2-114, Section 4.2] that crime can be displaced in five ways: temporal (e.g., from night to day), territorial (e.g., from relit area to non-relit area), tactical (e.g., from no use of force to use of force), target (e.g., from a drugstore to a school), and crime type (e.g., from robbery to burglary). Except for some analysis on temporal and territorial displacements of crime, the understanding of crime displacement is very minimal. Actually, perhaps the only valid method to ascertain crime displacement is to conduct an intensive and exhaustive offender interview program, including a sample of offenders who have *never* been incarcerated. Additionally, in the case of street lighting, it would be necessary to have specific environmental references for the interviewees to react to; that is, color slides of different night street environments may be required. This interviewing technique has been used in a study of residential crime [A.2-100].

Crime Measures Are Inadequate

Existing crime measures are defined by the Uniform Crime Report (UCR), which is published yearly by the Federal Bureau of Investigation (FBI). In essence, the FBI UCR classification of crime is based on *legal* definitions. From a research viewpoint, this method of classifying crime is lacking and not sensitive to the causal factors that contribute to the incidence of crime. For example, a more causal-oriented, classification method might categorize all crimes by motive (e.g., money, jealousy, etc.), locale of occurrence (e.g., on-street, off-street), time of occurrence (e.g., night, day), and character

of the neighborhood (e.g., slum, run-down, good, etc.). It is obvious that when crimes are classified on a causal-oriented basis and collected in the same manner, the search for solutions to crime problems can be more readily accomplished.

There are two arguments against adopting such a method. First, the causal factors of crime are not definitively known. Nevertheless, enough is known so that a *more* causal-oriented classification method can be established; the method could be refined as the causes of crime are better understood. Second, the amount of detail would make the data collection effort unmanageable. Undoubtedly, more data would have to be collected, but with current computer-based data processing techniques, the job would not be unmanageable. It is therefore suggested that intensive research be conducted to establish a problem-relevant, classification scheme of crime. The benefits appear to be worth the effort required.

A second problem with the UCR crime measures is that they only reflect those crimes which are reported to the police. Recent victimization surveys conducted by the National Crime Panel have confirmed what has long been speculated: a good fraction of crimes in cities are not reported to police departments. The surveys suggest that a major reason citizens don't call the police is a feeling of hopelessness that anything can be done to catch the offender. It seems plausible that if relighting enables victims to better recognize their attackers, they would be capable of providing better descriptions to authorities; thus, they might feel a call to the police is less likely to be a waste of time. Less tangibly, the very existence of a relighting project provides evidence that "somebody cares," which might in turn reduce the cynicism and hostility to authority that might otherwise thwart reports of crimes. This consideration might be particularly important in high-crime ghetto areas, which are often the first recipients of new street lighting. The net effect of these speculations is the suggestion that crime reporting rates may tend to go *up* in relit areas. Hence, an artificial increase in reported crime might occur, which would falsely work against the hypothesis that relighting can reduce crime; this presents a major problem in any study of street lighting and crime.

What can be done about the problem? There is no easy solution. By definition one does not know which citizens have *not* reported crimes against them. Victimization surveys, which ask respondents whether they were victimized by crimes they didn't report, can be helpful, but they require sample sizes of several thousand and are quite costly. Perhaps additional information could be obtained if some lighting experiments were coordinated with the victimization survey program being conducted by the National Crime Panel. It should be noted, however, that a victimization survey of residents in a relit area is not sufficient, since street crimes occur quite often to those who are transients in the area. Finally, it should be recognized that a lighting induced reporting rate change is important not only in connection with crime levels, but with arrest levels too, for crimes that are difficult to solve, which would earlier have been unknown to police, might be reported after relighting.

EXISTING ANALYTIC TECHNIQUES

The difficulties inherent in an evaluation of an experiment or program that is conducted in the real world are well known. Various analytic techniques--including regression analysis, time series analysis, and before/after analysis--have been applied to "discern" the impact of a particular intervention; there are weaknesses in each technique. Section 5.3 considers some of these weaknesses in the context of street lighting evaluations.

The potential synergistic effect of street lighting combined with one or more other interventions is even more difficult to evaluate. The classical method is to "control" for the number of interventions by having every intervention occur in a different target area, every combination of two interventions occur in a different target area, and so forth. Thus, if there are ℓ interventions, then a total of $(2^{\ell}-1)$ target areas are required, plus another area for control of other possible intervening variables. It is obvious that the number of target and control areas required for a large synergistic program, like the Crime Prevention Through Environmental Design (CPTED) program, would be unmanageable, if not impossible to define. Therefore, new analytic techniques, or hitherto unidentified use of existing techniques, are required to discern synergistic effects. Although the on-going evaluation of several CPTED programs should shed light on this issue, Section 6.3 recommends a research activity to be undertaken to identify and test analytic techniques which can be effectively used in street lighting evaluations.

POSSIBLE METHODOLOGICAL PROBLEMS

As stated in the street lighting issues discussion in Section 2, several possible methodological problems can be anticipated in an evaluation of street lighting and crime. In comparing these anticipated problems with those actually observed in the various evaluation studies (see Section 4.2), it is interesting to note that many more methodological problems are present in the evaluations. Although some of the methodological problems can be attributed to the difficulties encountered in carrying out an evaluation, most of the problems reflect a general naivete about how to design and conduct an evaluation. As discussed in Section 4.2, the observed problems are: research design is lacking; explanatory measures are lacking; impact measures are lacking; and analytic techniques are misused. It is hypothesized that if a model evaluation study was available as a guide, most of the observed methodological problems would not have occurred and the available evaluation findings would be more *conclusive* and *significant*.

PROPOSED EVALUATION DESIGN

The question of whether an evaluation design is cost-effective cannot be answered simply. It depends on which step--in the process that is identified in Exhibit 3.1--the evaluation is being pursued; that is, a first evaluation in the topic area should be costly since it involves pioneering efforts, while an evaluation that is modelled after another can be undertaken at minimal cost. Thus, it is not surprising that the 1974 Kansas City preventive patrol experiment cost more to evaluate than to conduct.

The cost-effectiveness of an evaluation is also dependent on other factors, including the relevance of the topic area, the need to collect data that are not readily available, and the anticipated usefulness of the evaluation findings. In any evaluation, there is always room to trade between cost and technical sophistication. Although many programs, especially LEAA-funded programs, allocate a fixed percentage--typically, three to five percent--of the total program budget to evaluation, it is recommended that each case be considered on its own merits.

PROJECT DATA UNIFORMITY

In a multi-project evaluation, it is of course important to have uniform data among the different projects. Section 2.1, however, discusses how the nature of project responsibility and the funding requirements make it very difficult to acquire data that are consistent and uniform. It is for this reason that no elaborate Phase I or multi-project evaluation can be carried out at this time, using the data contained in the available evaluation studies. For example, the fact that most projects refer to a target area simply as a "relit" area presents a difficulty in inter-project comparisons, since one project's relit area *could be* equivalent to another project's non-relit area.

Again, a *model* evaluation would allow projects to collect and maintain comparable data, in accordance with the design's measures framework requirements. Section 5.1 outlines such a measures framework.

3.2 SINGLE PROJECT EVALUATION

A general single project evaluation framework is identified in Exhibit 3.2; it is essentially composed of three sets of interrogatories which must be addressed before a single project evaluation design can be developed. In fact, in accordance with the evaluation process in Exhibit 3.1, the design contained in Section 5 is a detailing or *application* of the framework to the street lighting and crime topic area. Inasmuch as the elements of the framework are detailed in Section 5, this section concentrates on the approach taken by the framework.

As indicated in Exhibit 3.2, the framework is based on a *dynamic roll-back* approach. The roll-back dimension is apparent from the ordered sequence of steps indicated: the sequence "rolls back" in time from a) a projected consideration of the *total* project (i.e., from its rationale through its operation), the concurrent programs, and the *anticipated* end products of the evaluation; to b) a broad identification of the research design (i.e., test hypotheses, randomization/control scheme, measures framework, measurement methods, and analytic techniques), the data collection and processing procedures, and the impact analysis; and to c) a systematic review of the evaluation issues, which are discussed in the previous section, Section 3.1. Thus, the first step is a *forward* look at the total project and the end products, while the third and last step is a *near-term* look at those issues which may constrain the evaluation. The "dynamic" aspect of the approach refers to its *non-stationary* character; that is, the elements of the framework must constantly be refined, throughout the entire development and implementation phases of the single project evaluation design that is derived from the framework.

The dynamic roll-back approach is a means of *focussing* an evaluation design, so that it is purposeful and policy relevant. In projecting what will happen, the approach helps to identify problems or pitfalls that could hinder the evaluation. Additionally, the systemic nature of the approach assures its coverage of all pertinent evaluation requirements, components and issues. Finally, the robustness of the approach can be demonstrated by applying it to other NEP Phase I topic areas. The application to street lighting and crime is documented in Section 5.

3.3 MULTI-PROJECT EVALUATION

The multi-project evaluation framework is, as identified in Exhibit 3.2, essentially the single project evaluation framework together with an additional evaluation requirement, an additional evaluation component, and an additional evaluation issue, which is discussed in Section 3.1.

The additional evaluation requirement is simply that all projects should belong to the defined topic area. Actually, this requirement may not be as easy to satisfy as one might expect. Section 2, for example, relates the difficulty of defining a street lighting project.

The additional evaluation component is that of a project *typology*. A typology is a multi-dimensional matrix that categorizes the various projects in the topic area into groups, each of which contain "similar" projects. Similar projects refer to those projects that have common input or background elements. For example, street lighting projects that are implemented in commercial areas may not be similar to those that are implemented in residential areas. Each dimension of the matrix can be thought of as a background variable, such as land use, population, social demographic characteristic, lamp type, etc. It is obvious that, given a fixed number of projects, a large typology matrix implies a small number of projects within each matrix cell. On the other hand, a small typology matrix could result in an invalid research design.

Because of the small number of available evaluation studies in street lighting and crime and the fact that the data are lacking in both reliability and uniformity, it is not possible to conduct a Phase I or multi-project evaluation at this time. Thus, the next section, Section 4, summarizes the results of 15 evaluation studies, *without* attempting to perform a Phase I evaluation.

4 STREET LIGHTING EVALUATION

There has been a proliferation of articles and reports claiming that street lighting reduces crime. Exhibit 4.1 contains a list of street lighting projects which claim to have impacted crime. On closer examination, much of the supporting evidence behind these claims is based on the untested opinions of police chiefs, criminal justice administrators and urban planners. For example, a 1960 magazine article by Murray [A.2-91] is often cited in reports attempting to show the positive impact of street lighting on crime, since the article states that street lighting projects in over a dozen U.S. cities have decreased the number of incidents in one or more crime categories, including murder, rape, robbery, assault, burglary, auto thefts and vandalism. Most of Murray's claims are, however, based on the opinions of the cities' police chiefs, and no references are made to any studies or data sources except in the cases of New York City and Gary, Indiana.

In a later (1962) magazine article, Callender [A.2-17] gives a similar report, citing several of the claims made earlier by Murray. Former F.B.I. Director J. Edgar Hoover claimed in a 1963 article [A.2-56], and again later in a 1970 article [A.2-57], that it was a *fact* that street lighting deters crime. He went on to say that "in a survey of some 1300 police officials, 85 percent reported a drop in local crime rates." Hoover did not, however, point out the fact that the response rate of the survey was less than 10 percent, resulting in a possibly large, but unknown bias [A.1-27].

Exhibit 4.1

Some Reported Street Lighting Impacts

City [Reference]	Project Dates	Street Lighting Changes	Reported Impacts[1]
Asheville, NC [A.1-2]	1973	315 mercury vapor (21,000 lumen) replaced with high-pressure sodium (50,000 lumen)	Compared to 1972-1973, in 1973-1974, reductions in breaking and entering, larceny, vandalism, purse-snatches and hit and runs (by 40%)
Atlanta, GA [A.1-3]	1973-1974	Mercury vapor replaced with 191 high-pressure sodium (400 watt)	Discussed in analysis of Evaluation Sample
Baltimore, MD [A.1-6]	1969	Street lighting improved	Compared to June, 1968, in April, 1970 reductions in nighttime major crimes
Baltimore, MD [A.1-5]	1973-1974	High-pressure sodium installed	Discussed in analysis of Evaluation Sample
Chicago, IL [A.2-15]	1959	Several "districts" relit	Reductions in night robberies (by 30%), purse-snatches (by 30%), strong-arm robberies (by 87%) and auto thefts (by 10%) in some districts
Chicago, IL [A.2-82]	1966	51,000 mercury vapor installed in alleyways	Reductions in crimes in alleyways
Chicago, IL [A.1-9]	1974-1975	90,000 high-pressure sodium installed citywide	Discussed in analysis of Evaluation Sample
Cleveland, OH [A.2-82]	1966-1973	58,000 mercury vapor installed	Total crimes were increased (by 80%), but purse-snatches were reduced (by 78%)
Dade County, FL [A.2-106]	1972	Incandescent (100 watt) replaced with mercury vapor (250 watt) in a public housing project	In a nine-month period, reductions in Part I crimes (245 to 189) and in Part II crimes (72 to 35)
Denver, CO [A.1-15, A.1-16]	1975-1976	1,500 high-pressure sodium (400 watt) installed in a mixed residential and commercial area	Discussed in analysis of Evaluation Sample
Detroit, MI [A.2-82]	1968	675 mercury vapor installed	Reductions in night crimes (by 12%) in relit area and increase (by 14%) in "control" area
East Orange, NJ [A.3-18]	1971-1973	368 mercury vapor installed	Reductions in night Part I crimes in relit area (by 16%)
Flint, MI [A.2-98]	1956	Incandescent (6,000 lumen) replaced with mercury vapor (20,000 lumen)	Reductions in felonies and misdemeanors (by 60%) and in larcenies (by 80%)
Gary, IN [A.2-68]	1953-1955	Mercury vapor installed in dimly lit areas	Reductions in assaults (by 70%) and robberies (by 60%)
Harrisburg, PA [A.1-21]	1975-1976	229 high-pressure sodium installed in a mixed residential and commercial area	Discussed in analysis of Evaluation Sample

[1]Where available, the periods of comparison are quoted; in most instances, the periods of comparison were not indicated in the published accounts of the impact.

Exhibit 4.1

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City [Reference]	Project Dates	Street Lighting Changes	Reported Impacts
Indianapolis, IN [A.2-25]	1959-1962	900 mercury vapor and 100 fluorescent installed per year	The year after light improvement, reductions in night crimes (by 60%) and total crimes (by 255) in relit areas
Jeffersontown, KY [A.1-27]	1973-1976	Mercury vapor installed in a new residential area	The following were observed: (i) fewer burglaries and thefts in well-lit as compared to poorly-lit areas; (ii) residents believed that street lights deter crime; and (iii) residents had positive attitudes toward street lighting
Kansas City, MO [A.2-15]	1950-1953	40% of streets relit in 1950-1951, 65% of streets relit in 1952-1953	Reduction in the ratio of night to day crimes citywide, and higher reduction on better lit streets
Kansas City, MO [A.1-30, A.1-31, A.1-32]	1971-1972	1206 mercury vapor and 594 high-pressure sodium installed in downtown area and in a mixed residential and commercial area	Discussed in analysis of Evaluation Sample
Miami, FL [A.1-37]	1971-1972	350 high-pressure sodium (47,000 lumen) installed	In 1971, dramatic reductions in crimes in the garment district, due to increased patrol activity combined with new lights
Miami, FL [A.1-38]	1972-1977	High-pressure sodium installed citywide	Discussed in analysis of Evaluation Sample
Milwaukee, WI [A.1-42, A.1-44]	1972	130 incandescent replaced with high-pressure sodium (250 watt)	Discussed in analysis of Evaluation Sample
Newark, NJ [A.1-46, A.1-47]	1973-1974	762 mercury vapor installed in a mixed residential and commerical area	Discussed in analysis of Evaluation Sample
New Orleans, LA [A.1-50, A.1-51]	1973-1975	559 mercury vapor (400 watt) installed	Discussed in analysis of Evaluation Sample
New York, NY [A.2-98]	1957	Incandescent replaced with mercury vapor in 111 blocks	Reduction in night crimes (by 49%)
New York, NY [A.1-53]	1959-1961	Lighting improved in 392 playgrounds	Reductions in vandalism (by 100% in Staten Island, by 86% in Brooklyn, by 81% in Manhattan, by 50% in the Bronx and Queens)
Norfolk, VA [A.1-57, A.1-58, A.1-59]	1972-1974	Mercury vapor (100 watt) installed in a residential area	Discussed in analysis of Evaluation Sample
Norman, OK [A.3-72]	1973	28 high-pressure sodium installed in a residential area	Reduction in burglaries (31 to 9) compared with a citywide increase (of 10%)
Owensboro, KY [A.2-6]	1968-1970	5,000 mercury vapor installed	From 1969 to 1970, reduction in major crimes (by 38%), compared with increases in neighboring towns

Exhibit 4.1
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City [Reference]	Project Date	Street Lighting Changes	Reported Impacts
Plainfield, NJ [A.1-61]	1972-1973	136 high-pressure sodium installed in downtown area	Reductions in burglaries (by 50%) and robberies (by 65%)
Portland, OR [A.1-63, A.1-66]	1972-1973	330 mercury vapor (175 watt) installed in a residential area	Discussed in analysis of Evaluation Sample
Richmond, VA [A.1-67]	1972-1973	404 high-pressure sodium and 457 mercury vapor installed in a mixed residential and commercial area	Discussed in analysis of Evaluation Sample
Savannah, GA [A.1-69, A.1-70]	1970-1975	Incandescent replaced with high-pressure sodium and mercury vapor	Reductions in crimes and vandalism (by as much as 50%)
St. Louis, MO [A.2-92]	1962-1964	1,402 incandescent replaced with 1,120 mercury vapor (1,000 watt) in downtown area	An increase in nighttime business and reductions in crimes against persons (by 40%), auto theft (by 28.6%), and business burglaries (by 12.7%)
Tucson, AZ [A.1-74]	1966	Street lighting improved	Reduction in total crimes (by 50%)
Tucson, AZ [A.1-75]	1971	277 mercury vapor (175 watt) installed in a residential area	Discussed in analysis of Evaluation Sample
Washington, D.C. [A.1-76]	1970	High-pressure sodium installed in 113 high-crime blocks	Discussed in analysis of Evaluation Sample

Beginning in 1965, a series of three studies was conducted for the Education and Public Welfare Division of the Legislative Reference Service of the Library of Congress, entitled "The Impact of Street Lighting on Crime and Traffic Accidents" [A.2-6, A.2-7, A.2-68]. Although the studies give a good review of the subject matter, the first two cite the same often-quoted statistics and opinions described above, and the authors only mention the *positive* statistics and opinions. Yet these studies have been used by congressmen and senators in connection with debates over bills designed to fund street lighting projects [A.2-24].

In contrast to the above-mentioned positive claims, other reviews of street lighting and crime have emphasized the caution required in interpreting these claims. Two of these, the reports of the National Advisory Commission on Criminal Justice Standards and Goals [A.2-92] and the President's Commission on Law Enforcement and Administration of Justice [A.2-98], have already been cited in Section 1. In a special report to the Public Works Committee of the U.S. House of Representatives, 89th Congress, Box [A.2-14] states that, although public officials and law-enforcement officers agree that lighting deters crime, "the fact is not sufficiently documented." He cites a few experiences of crime reduction after improvement of street lighting in some cities, but points out that the data collection procedures and the sundry other factors affecting crime rates must also be carefully considered before specific conclusions can be drawn. The third Library of Congress study also cautions that [A.2-6, p. 4]:

> Since it was generally not feasible to control for other possible causes (e.g., weather, number of police in a given area, economic conditions), the conclusion that the reductions were due to improved street lighting must generally be viewed as conjectural or intuitive, rather than scientific.

It is, of course, the purpose of this study to critically analyze the various claims. In accordance with the sample selection process identified in Exhibit 1.4, an Evaluation Sample of projects was identified as the basis for such an analysis. Background information on the Evaluation Sample projects is contained in Exhibit 4.2. Given the fact that the projects had to have a crime-related focus, it is not surprising to see that the majority of projects are funded by the LEAA.

The remainder of this section concentrates on the Evaluation Sample projects. However, because there are only 15 projects in the sample, and because the project data are non-uniform, a *formal* Phase I or multi-project evaluation cannot be conducted at this time. Nevertheless, a systematic analysis of individual project evaluations is undertaken; each project is analyzed in terms of the components of the single project evaluation design that is identified in Exhibit 5.1 and discussed in Section 5. More specifically, Section 4.1 describes and highlights key aspects of the projects' research designs; Section 4.2 identifies

Exhibit 4.2

Street Lighting Projects: Evaluation Sample

City [Reference]	Project Dates[1]	Funding Source[2]	Target Area(s) Land Use	Target Area(s) Size	Light Source Type[3]	Evaluator[4]	Crime-Related Objectives	Impact Measures
1. Atlanta, GA [A.1-3]	1973-1974	LEAA, Local	Central Business	14 blocks	HPS	Impact Program	• Reduce night Part I crimes, each by 5-15% within one year	Crime
2. Baltimore, MD [A.1-5]	1973-1974	LEAA, Local	Not Available (n.a.)	n.a.	HPS	CJCC	• Not stated	Attitudes, Behavior, Crime
3. Chicago, IL [A.1-9]	1974-1975	Local	Citywide	3000 miles	HPS	Police Department	• Reduce citywide crime	Crime
4. Denver, CO [A.1-16]	1975-1976	LEAA, Local	Residential, Commercial, Schools	2.39 square miles	HPS	CJCC	• Reduce citizens' fear of crime • Increase night pedestrian activity • Increase night rape, robbery, assault, burglary clearance rate, each by 10% • Reduce night rape, robbery, assault, burglary, each by 25-50%	Attitudes, Crime
5. Harrisburg, PA [A.1-21]	1975-1976	LEAA, Local	Residential, Commercial	30 blocks	HPS	Police Department	• Reduce citizens' fear of crime • Reduce robbery, assault, burglary, auto theft, each by 5-20%	Attitudes, Behavior, Crime
6. Kansas City, MO [A.1-30, A.1-31, A.1-32]	1971-1972	Local	Central Business Residential, Commercial	500 blocks	HPS, MV	Consultant	• Reduce crime	Crime
7. Miami, FL [A.1-38]	1972-1977	Local	Citywide	34 square miles	HPS	Public Works Department	• Not stated	Crime
8. Milwaukee, WI [A.1-42, A.1-44]	1972	LEAA, Local	Residential	3.5 miles	HPS	CJCC	• Reduce crime • Increase police capability to detect crime	Attitudes, Behavior, Crime
9. Newark, NJ [A.1-46, A.1-47]	1973-1974	LEAA, Local	Residential, Commercial	n.a.	MV	Impact Program	• Reduce target area murder, rape, robbery, assault and burglary, each by 7.5% within one year • Reduce citywide murder, rape, robbery, assault and burglary, each by 1.6% within one year	Crime

[1]Calendar years during which planning and installation activites were supposed to have taken place.

[2]LEAA: Law Enforcement Assistance Administration; HUD: U.S. Department of Housing and Urban Development.

[3]FL: fluorescent; HPS: high-pressure sodium; LPS: low-pressure sodium; MH: metal halide; MV: mercury vapor.

[4]CJCC: Criminal Justice Coordinating Council; SPA: State Planning Agency.

Exhibit 4.2

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City [Reference]	Project Dates[1]	Funding Source[2]	Target Area(s) Land Use	Target Area(s) Size	Light Source Type[3]	Evaluator[4]	Crime-Related Objectives	Impact Measures
10. New Orleans, LA [A.1-49, A.1-50]	1973-1975	LEAA, Local	Residential	170 blocks	MV	CJCC	• Reduce night assault, burglary and auto theft	Crime
11. Norfolk, VA [A.1-59]	1972-1974	HUD	Residential	11.5 square miles	MV	Consultant	• Promote sense of security • Invite night street use	Attitudes, Behavior
12. Portland, OR [A.1-63, A.1-66]	1972-1973	LEAA, Local	Residential	315 blocks	MV	SPA, Consultant	• Reduce stranger-to-stranger street crimes	Attitudes, Crime
13. Richmond, VA [A.1-67]	1972-1973	LEAA, Local	Residential, Commercial	n.a.	HPS, MV	Consultant	• Reduce burglary	Crime
14. Tucson, AZ [A.1-75]	1971	LEAA, Local	Residential	5.8 square miles	MV	Model City Agency	• Reduce Part I crimes, each by 5% per year for two years • Increase citizens' feeling of safety	Attitudes, Crime
15. Washington, DC [A.1-76, A.1-77]	1970	U.S. Congress	Residential Commercial	113 blocks	HPS	Traffic Engineering Department	• Reduce crime • Return the streets to the people	Crime

the methodological problems which pervade the project evaluations; and Section 4.3 critically assesses the crime-related impact results.

Again, as in Section 2, no elaborate statistical analysis is attempted in this section; the small sample size precludes the need for such an analysis. However, a detailed and critical analysis of the project evaluations is contained in this section, so that future street lighting evaluations can profit from the analysis.

4.1 RESEARCH DESIGNS

The research design of a project is the *plan* by which the project is to be evaluated. Ideally, the research design should be developed in coordination with the project development, *prior* to the project's implementation. The ideal was realized in only a few of the Evaluation Sample projects.

Each component of the research design (i.e., test hypotheses, randomization/control scheme, measures framework, measurement methods, and analytic techniques) is discussed in this section. The discussion is based on the contents of Exhibit 4.3, and it serves to provide a basis for interpreting the methodological problems and impact results that are addressed in Sections 4.2 and 4.3, respectively.

TEST HYPOTHESES

The Evaluation Sample does not contain a rich set of alternative test hypotheses regarding the impact of street lighting on crime. Given the qualitative and incomplete nature of the

Exhibit 4.3

Evaluation Sample: Research Designs

City	Test Hypotheses	Randomization/ Control Scheme	Measures Framework: Input	Measures Framework: Process	Measures Framework: Impact	Measurement Methods	Analytic Techniques
Atlanta, GA	• Increased street lighting reduces crime • Increased street lighting displaces night crime to adjacent areas and to daytime	• Control area: surrounding census tract, excluding target area	• Not well defined	• Not well defined	• Crime: reported night/day Part I crime	• Not stated	• Before/after comparison; χ^2 test Before/after, target/control area comparisons; χ^2 test
Baltimore, MD	• Not stated	• Not stated	• Not well defined	• Not well defined	• Attitude: residents' reported change in perceived crime rate and feeling of safety • Behavior: residents' reported change in own night street use • Crime: reported night/day street robbery, residential robbery and rape	• Attitude: 15% sample of target area residences, 3 months after installation completed	• Tabulation of post-street lighting survey data • Before/after comparison of crime data
Chicago, IL	• Not stated	• Target Area: city	• Not well defined	• Not well defined	• Crime: reported night incidence of each crime	• Not stated	• Before/after comparison
Denver, CO	• Increased street lighting reduces fear of crime • Increased street lighting increases night street use • Increased street lighting increases police effectiveness • Increased street lighting reduces crime	• Control areas: adjacent area and city (excluding target and adjacent area)	• Not well defined except for environmental constraints, performance specifications, and target area	• Not well defined except for concurrent law enforcement programs	• Attitude: residents' reported change in feeling of safety • Behavior: residents' reported changes in own night street use and reporting of crime • Crime: reported night rape, robbery, assault, and burglary	• Attitude and behavior: random sample of target area residences (sample size = 118; response rate not stated) • Crime: machine-readable reported crime data	• Tabulation of post-street lighting survey data • Before/after, target/control area comparisons of crime data; t-test
Harrisburg, PA	• Increased street lighting reduces fear of crime	• Control areas: adjacent area and city (excluding target and adjacent area)	• Not well defined except for system design and target area	• Not well defined	• Attitude: residents', small business owners and foot patrolmen's preference for new street lighting and reported change in feeling of safety • Behavior: foot patrolmen's reported change in own effectiveness • Crime: reported night robbery, assault, burglary and auto theft	• Attitude and behavior: sample size of residents is 25, of business owners, 9, and of foot patrolmen, 16 (100% response). Resident and business owner sampling method and response rate not stated	• Tabulation of post-street lighting survey data • Before/after, target/control area comparisons of crime data

Exhibit 4.3

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City	Test Hypotheses	Randomization/ Control Scheme	Measures Framework: Input	Process	Impact	Measurement Methods	Analytic Techniques
Kansas City, MO	• Increased street lighting reduces crime • Increased street lighting reduces night street crime: in relit blocks more than in non-relit blocks; to different degrees in residential and commercial blocks; and to different degrees for residential and commerical burglary targets • Increased street lighting displaces some night street crime	• Target and control areas: stratified samples of relit, non-relit blocks, respectively	• Not well defined except for system design and target area	• Not well defined except for system output	• Crime: reported night/day, street/non-street robbery, assault, burglary, auto theft and larceny	• Machine-readable, reported crime data, geocoded by block • Field measurement of horizontal illumination and uniformity, using specially-designed vehicle mounted recording photometers. Final impact analyses do not make use of measurements	• Before/after, target/control, street/non-street, residential/commercial area comparisons; χ^2 test
Miami, FL	• Not stated	• Target area: central business district and adjacent residential area (1.8 square miles) • Control area: city	• Not well defined except for performance specifications and system design	• Not well defined	• Crime: reported night Part I crime	• Not stated	• Before/after, target/control area comparisons
Milwaukee, WI	• Increased street lighting reduces night crime • Increased street lighting displaces night crime to adjacent areas and to daytime	• Control area: adjacent area	• Not well defined except for funding source and target area	• Not well defined except for design verification	• Attitude: residents' and patrolmen's preference for new street lighting; and reported changes in feeling of safety and in perceived crime. • Behavior: residents' reported change in own night street use. Patrolmen's reported change in own effectiveness • Crime: reported night crime	• Attitude: sample of residents (sample size = 294; response rate = 42%) and of police patrolmen (sample size = 16; response rate = 100%)	• Tabulation of post-street lighting survey data • Before/after, target/control area comparisons of crime data
Newark, NJ	• Increased street lighting reduces night crime	• Control area: city	• Not well defined	• Not well defined except for design verification and concurrent law enforcement program	• Behavior (police effectiveness): number of arrests and clearance rate for each Part I crime • Crime: reported total and night, indoor and outdoor Part I crimes	• Not stated	• Before/during/after, target/control area comparisons

Exhibit 4.3

(page 3 of 4)

City	Test Hypotheses	Randomization/ Control Scheme	Measures Framework			Measurement Methods	Analytic Techniques
			Input	Process	Impact		
New Orleans, LA	• Increased street lighting reduces night crime	• Control areas: two adjacent areas and city (excluding target area)	• Not well defined except for funding source and target area	• Not well defined except for design verification	• Crime: reported night business burglary, assault and auto theft	• Machine-readable, reported crime data, verified against manually collected data	• Before/after, target/control area comparisons; interrupt time series
Norfolk, VA	• Street lighting systems with relatively higher uniformity, lower illumination, fewer shadows and lower color temperature result in test subjects' higher overall rating, sense of security and willingness to use streets at night	• Test subjects consisted of a random sample of residents; they were randomly exposed to target and control environments	• Not well defined except for environmental constraints, performance specifications, system design, and target area	• Not well defined except for design verification and system output	• Attitude: test subjects' overall rating of brightness, glare, warmth, uniformity, color rendition, appropriateness and desirability • Behavior: test subjects' reported frequency, purpose and tactics of own night street use	• Random sample of residents of target area and a non-adjacent control area to be test subjects (sample size = 125; response rate = 31%) • Horizontal illumination was measured at 10-foot intervals along roadway and sidewalk center lines	• Target/control area comparison of some input, process and impact measures • Impact measures regressed on collected input and process measures; multiple regression
Portland, OR	• Increased street lighting reduces night robbery, assault and burglary, relative to comparable areas without increased lighting • Increased street lighting displaces some night robbery, assault and burglary	• Control areas: areas adjacent to target areas (i.e., "displacement" areas); and areas adjacent to "displacement" areas	• Not well defined except for system design and target area	• Not well defined except for installation cost	• Attitude: residents' awareness of street lighting increase, perception of "how well lighted" target area is; and reported changes in feeling of safety • Crime: reported night robbery, assault and burglary	• Random sample of residents of target area and other areas of SMSA (target area sample size = 350; other sample sizes and response rates not stated)	• Tabulation of post-street lighting survey data • Target/control area comparison of associations between street lighting attitudes • Before/after, target/control area comparisons of crime data • Two-way (before/after; target/control area) analysis of crime data variance.

Exhibit 4.3

(page 4 of 4)

City	Test Hypotheses	Randomization/ Control Scheme	Measures Framework			Measurement Methods	Analytic Techniques
			Input	Process	Impact		
Richmond, VA	• Not stated	• Not stated	• Not well defined except for system design and target area	• Not well defined except for design verification, installation cost and concurrent law enforcement program	• Crime: reported residential/non-residential burglary	• Not stated	• Before/after comparison
Tucson, AZ	• Not stated	• Control area: a portion of the street lighting area was randomly selected for late installation of street lights (i.e., after completion of attitude surveys) • Target area: the balance of the street lighting area	• Not well defined except for funding sources and system design	• Not well defined except for concurrent law enforcement, physical and social programs	• Attitude: residents' feeling of safety. • Crime: reported Part I crime	• Attitude: random sample of target and control area residents, before and after target area installation (total sample size = "several hundred"; response rate not stated)	• Before/after, target/control area comparisons of survey results • Time series analysis of crime data (entire street lighting area)
Washington, DC	• Increased street lighting reduces night crime	• Not stated	• Not well defined except for target area	• Not well defined except for operating cost	• Crime: reported night robbery, residential burglary, auto theft and vandalism	• Not stated	• Before/after comparison

projects' objectives, this observation is not surprising. In fact, most of the Evaluation Sample reports do not even state explicit test hypotheses; many of the hypotheses listed in Exhibit 4.3 are constructed from statements that appear to *imply* their existence.

In contrast to the other projects, the Kansas City and New Orleans projects give the most consideration to the definition of test hypotheses as the starting point of a research design. In the Kansas City case, a detailed set of *research questions* is given, the answers to which are intended to yield the expected impacts of street lighting. For example, one of the research questions is, "How does the relation between night street crime and other types of crime in relit areas compare to that same relation in non-relit areas?" Each research question is then replaced by a *test hypothesis*. In the example given above, the corresponding test hypothesis is, "The decrease in night street crime, relative to night non-street or day street offenses, will be greater for relit than for non-relit blocks."

On the other hand, the New Orleans project analyzes the *target crimes* involved in the test hypotheses. Noting the absence of a body of knowledge about how street lights reduce crime and about which crime types and methods of operation are expected to be reduced, the project focuses on the three crime types which, based on historical data, have been shown to be relative stable and to occur relatively more frequently at night;

they are business burglary, assault and auto theft. The project observes that, although these target crimes are the ones most likely to be reduced, none is a "pure" nighttime crime, so that an explicit hypothesis would be limited and, therefore, not warranted.

RANDOMIZATION/CONTROL SCHEME

As noted in Section 5.2, it is not possible for a public service like street lighting to be *randomly* assigned to target areas in a manner consistent with a classical research design. Nevertheless, one project did randomize the areas which received early and late lighting installations. On the other hand, all, except four, of the projects identified one or more control areas.

Randomization

In one project--Tucson--the area selected for alley lighting was divided into sub-areas which were randomly scheduled for early and late lighting installation. On the assumption that the alley lighting area was itself homogeneous, this procedure created a target (i.e., early installation) area and a control (i.e., late installation) area.

Although limited to a short time period--most likely too short for the discernment of crime impacts--the Tucson randomization technique could be used in other social experimentation settings.

Control

Two approaches to the identification of control areas appear in the Evaluation Sample. The first, and most prevalent, approach consists either of using the entire city as a control area or of selecting a group of city blocks adjacent to the street lighting target area, usually chosen for convenience in collecting reported crime data. Typically, no effort is made to explain why adjacent areas are selected other than stating the *assumption* that adjacent areas are expected to be similar in all respects to the target area, except for relighting. The danger in using adjacent areas as control is that these could be the *same* areas to which crime is displaced from the target area!

In the second approach, used only by Kansas City, individual blocks of both a large relit area and the rest of the city are sampled on a stratified, random basis, resulting in sets of relit (i.e., target area) and non-relit (i.e., control area) blocks which are "matched" according to socio-economic indicators.

It is interesting to note that the New Orleans project admitted that it was difficult to match areas *simultaneously* for crime levels and social indicators. As stated in Section 4.2, similar difficulties are observed in the Kansas City and Portland control areas, although these difficulties are not explicitly alluded to in the project reports.

MEASURES FRAMEWORK

The measures framework provides a means of relating the explanatory (i.e., input and process) measures and impact measures. As is stated in Section 5.1, all the input and process measures should be identified since any one or combination of them could cause or explain an impact result. Unfortunately, the Evaluation Sample projects lack specificity in their identification of input, process and impact measures.*

Input Measures

For the most part, the input measures included in the Evaluation Sample projects consist only of measures characterizing the project plan (i.e., performance specifications, system design and target area). A comparison with the *recommended* measures framework in Exhibit 5.1 highlights the multitude of other possible input measures that are generally missing in the Evaluation Sample. The only exceptions are two projects--Denver and Norfolk--which describe environmental constraints in narrative form, and several projects which identify the sources of funds.

When provided at all, information on performance specifications is incomplete, usually stating average horizontal illumination for a typical roadway--rather than a walkway--surface. Only Miami gives a complete performance specification, identifying it as a slightly modified IES specification.

System design measures usually consist of identification of the light source type and/or wattage. Other details, such as information

*Reported impacts based on these measures are discussed in Section 4.3.

on the luminaires, mounting equipment and electrical system are lacking, and virtually no information is provided on the system designs which were replaced by the street lighting projects.

Finally, when target area information is given, it tends to consist of area boundaries and size, and an overall land use indicator (i.e., residential, commercial, etc.), sometimes supplemented by a set of social indicators (e.g., racial character, age distribution, population density, income distribution, etc.). However, two other potentially important target area measures are completely lacking: the procedures and criteria for selecting the target area; and information on environmental conditions relevant to the potential ability of the street lighting system to prevent crime.

Process Measures

Apart from a few projects reporting on design verification (i.e., changes in or confirmation of project schedule, system design, and target area), the only other process measures reported on are those of system output and concurrent law enforcement programs.

In terms of system output, only two projects--Kansas City and Norfolk--include actual light measures. Both projects determined average horizontal illumination and uniformity on the roadway. Norfolk, in addition, measured vertical illumination, and obtained sidewalk as well as roadway data. In the Portland project, the survey interviewers counted the number of street lights visible from the front entrance of each respondent's house, and their number is used in the study as a proxy for light output. In none of the other projects are light measures made--only the dichotomy, relit/non-relit, is employed.

Finally, concurrent law enforcement programs are noted in narrative form in only a few evaluations (i.e., Denver, Newark, Richmond and Tucson). However, no quantitative information (e.g., on changes in tactics or patrol level) is given. Interestingly, in a number of other cities where concurrent law enforcement programs are *known* to have taken place (i.e., Atlanta, Baltimore, Kansas City, New Orleans and Portland), not even qualitative information is given. While other concurrent physical and social programs could have affected crime or other impact measures, only one evaluation--Tucson--describes these programs in any detail. The methodological problems created by these shortcomings are reviewed in Section 4.2.

Impact Measures

Street lighting impact measures include measures of attitude, behavior and crime, and all three types are mentioned in the Evaluation Sample.

Attitude

Among measures of attitude, the most common are citizens' or police officers' *reported changes* in feelings of safety and/or related attitudes. The typical survey question is, "Since the addition of the new street lights, do you generally feel safer, the same or not as safe?" Another less frequently asked question is, "Do you believe the new street lighting has helped to reduce crime in your neighborhood?"

In a more detailed approach to ascertaining attitude, used only by Norfolk, semantic differential ratings of various attitudes regarding the street lighting project or its surrounding environment are obtained. This technique involves establishing a scale between two adjectives or phrases. An example of this technique is [A.1-59, p 112]:

How would you describe the lighting in this environment? (Circle one number in each row.)

too bright	1	2	3	4	5	6	7	too dark
pleasant	1	2	3	4	5	6	7	unpleasant
.				.				.
.				.				.
.				.				.
.				.				.
.				.				.
too many shadows	1	2	3	4	5	6	7	no shadows

Semantic differential ratings focus on the *absolute* magnitude of attitudes at a single point in time, rather than relying on *reported changes* in attitude. This procedure facilitates direct comparisons of attitudes at different points in time, or concerning different environments.

Behavior

As with attitude measures, the behavioral measures used in the Evaluation Sample include self-reported changes in behavior. In addition, the number of arrests and clearance rate are used in one project as indicators of police patrol effectiveness. The typical question asked to determine target area residents' reported change in behavior is, "Have the new street lights permitted you to go out more during the evening than you had before?" Foot patrolmen were asked such questions as "Has the efficiency of your patrol been increased because of this type of lighting", "Has the new lighting assisted you in apprehending any criminals or suspects?" and "Does the new street lighting improve your ability to assist an officer in trouble?" All of the above questions provided for yes/no answers and none probes for details as to *how* the street lights support the behavior in question.

Again, the Norfolk project has more detailed behavioral questions. The frequency of night street use is asked for a variety of activities (e.g., going to and from parked cars, taking a walk alone for pleasure, walking to a nearby store, etc.). In addition, a series of open-ended questions probes for the factors and conditions which limit and encourage the respondents' night street use.

Finally, the Newark evaluation uses the total number of arrests and clearance rates for each Part I crime, before and after relighting, as proxies for police patrol effectiveness. Neither the arrest nor the clearance data, however, is normalized to the total number of patrol-hours and the data do not distinguish between day and night statistics.

Crime

As might be expected, every project in the Evaluation Sample uses *reported crime* as the measurement of crime level. Reported crime was usually obtained for night crime only, although several projects give night and day incidence and a few give only the total (i.e., night and day combined) crime. The target crimes for which data were obtained are generally the Part I crimes of robbery, assault, burglary, auto theft and larceny. A few projects include murder and rape and, occasionally, other classifications are employed (e.g., Index/Non-Index crimes and crimes against person/crimes against property). Breakdowns for street/non-street location and, in the case of burglary, residential/commercial are made infrequently. Only the Kansas City evaluation provides data broken down in all of the above ways. One project--Newark--gives number of complaints as a crime measure, but it does not define the measure clearly and little use is made of it in the analysis.

MEASUREMENT METHODS

The methods or procedures to measure the input, process and impact measures are usually not well defined in the Evaluation Sample.

Input Measurement

No input measurement methods are discussed in the Evaluation Sample.

Process Measurement

Two projects--Kansas City and Norfolk--identify light output measurements. Kansas City used a continuously recording light meter, mounted on a vehicle, to measure the horizontal illumination at the center of the roadway. The average value for each of 1200 sample blocks was hand-calculated and coded onto the data file. Unfortunately, the final Kansas City evaluation did not make use of this data base--one reason was that the light measurements were not reliable.

In Norfolk, the distance between street lights was divided into ten-foot intervals and horizontal and vertical illumination measurements were made at these intervals, along each sidewalk and the center of each driving lane. Results were plotted as isolux diagrams* on maps which also showed the location and extent of tree foliage. Average values and uniformity ratios are also listed on the maps.

Impact Measurements

While the selection of street light target *areas* has rarely been made on the basis of random selection, the same is not true for *test subjects* whose attitudes are to be measured. In the Norfolk evaluation, a sample of test subjects** was randomly assigned to

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* See Appendix B for an explanation of isolux diagrams.

** Test subjects consisted of randomly selected residents from two neighborhoods: the target area and an area which resembled the target area both physically and in terms of social, economic and demographic characteristics.

walk or drive through different combinations of 19 target and control area environments. Each pedestrian environment was one block long and the set of environments was chosen to provide a sharply contrasting variation in patterns of illumination level and uniformity as well as other characteristics. Before the experiment, these subjects answered questions concerning their attitudes toward, and typical patterns of use of, streets at night. After walking or driving through a given set of environments, test subjects' attitudes toward the environments were measured in a second interview.

The Norfolk evaluation is unique among evaluations addressing attitude or behavior measures in that it directly compares attitudes about a target area with those about a control area. The evaluation itself points out that the generalizability of its findings is limited by the specific nature of the environments tested and by the population chosen to be test subjects.

Except for the Norfolk project, measurement methods for attitudes and behavior are rarely given in detail. While sample *sizes* are usually stated, sampling *rates* and *response rates* are not. Available information on resident surveys indicates sample sizes ranging from 25 to 350. The only two response rates quoted are Norfolk's (31 percent) and Milwaukee's (42 percent).

Similarly, descriptions of measurement methods for reported crime are largely absent. A few projects report the data sources to be computer tapes or printouts and two of them--Kansas City and New Orleans--report checking machine-readable data by hand for errors and inconsistencies. The context of most projects implies that the reported crime data are simply tabulated from monthly Uniform Crime Report (UCR) forms, for the reporting districts corresponding to the target or control areas.

ANALYTIC TECHNIQUES

The analytic techniques used by the Evaluation Sample projects are before/after analysis, regression analysis and time series analysis.

Before/After Analysis

This most widely used of the three techniques indicated above is most conveniently described in terms of three categories: tabulation of post-street lighting survey data, simple (i.e., before/after) comparisons and controlled (i.e., before/after, target/control area) comparisons.

Because of the questions of reported changes in attitude, tabulation of post-street lighting survey data constitutes an *implicit* before/after comparison in every attitude and behavior evaluation, except in the case of Norfolk, which, as noted earlier, used semantic differential ratings.

The explicit before/after comparisons are, with the exception of Tucson's attitude study, all performed on reported crime data. The majority employ straightforward comparisons of before/after, target/control area data; Baltimore, Chicago, Richmond and Washington, D.C. did not have control areas.

"Before" periods range in number and duration from a single period of 139 days (Chicago) to four one-year periods (New Orleans). "After" periods range from a single 139-day period (Chicago) to two one-year periods (New Orleans). If anything were to be called typical, it might be several one-year "before" periods and a single one-year "after" period.

The Kansas City evaluation provides the most detailed set of comparisons. Utilizing the ability of the data to be refined further into street/non-street, day/night and residential/commercial categories, an elaborate series of comparisons is performed both within the target area and between the target and control areas.

Only two studies--Kansas City and Portland--analyze crime displacement and both do so within the context of before/after, target/control area comparisons. Kansas City computes the magnitude of temporal and territorial displacements by calculating the trend in the baseline period and extrapolating it to the test period. The *differences* between extrapolated and actual crime frequencies in the target and displacement areas are labelled "prevented" and "excess" crime, respectively. When prevented crimes exceed excess crimes, displacement is assumed to have occurred. In this fashion, the Kansas City evaluation examines displacement of night street crime from relit blocks to non-relit blocks, to night non-street crime in relit blocks, and to day street crime in relit blocks. The Kansas City evaluators note that their analysis of territorial displacement is somewhat limited, inasmuch as the displacement blocks are selected based upon logic rather than actual knowledge from an offender interview program.

Tests of significance are performed only by four projects--Atlanta, Denver, Kansas City and Portland--and include the chi-square test, the t-test and the analysis of variance. There are, however, some problems with the application of these tests, as discussed in Section 4.2.

Regression Analysis

This technique is only used in the Norfolk evaluation. Here the dependent variables are various test subject attitudes about target and control environments. The independent variables include: other test subject ratings of the lighting and overall environment; and objective measures of system output (i.e., average horizontal illumination and uniformity ratio on the roadway and the sidewalks). Separate analyses are performed for pedestrian ratings of residential and arterial streets, and for driver ratings of all street types.

Each data point in the Norfolk multiple regression analysis corresponds to the mean score of each variable for a particular test environment. Because of the small number of environments (19), the number of independent variables in any equation is reduced to the three providing the best relationship with the dependent variable.

Time Series Analysis

Time series analysis is reported in the New Orleans and Tucson evaluations. Only the former describes its time series technique explicitly.

In the New Orleans evaluation, for each target crime and for each target and control area, an interrupted time series, together with a step-wise regression/correlation analysis, is performed on data consisting of 50 one-month "before" intervals and 29 one-month "after" intervals. The analysis results in a set of correlation coefficients whose relative signs and magnitudes are expected to behave in a certain way if there is crime reduction in the target area, relative to the control areas.

4.2 METHODOLOGICAL PROBLEMS

Although there is no universal agreement on the definition of the term "evaluation," the one by Suchman clearly states all the major required dimensions [A.2-111, p. 28]:

> The process of determining the value or amount of success in achieving a predetermined objective. It includes at least the following steps: formulation of the objective, identification of the proper criteria to be used in measuring success, determination and explanation of the degree of success, and recommendation for further program activity.

It is clear from a comparison of this inclusive definition with the research designs described in Section 4.1 that most of the Evaluation Sample studies fail to fall into the category of true evaluations.

In this section the implications of the Evaluation Sample's shortcomings, in both research design and evaluation conduct, are discussed in greater detail, as background to the discussion and interpretation of the limited, and often contradictory, impact results presented in Section 4.3.

The first methodological problem is, of course, that research design is lacking. There are, additionally, three other problems associated with specific elements of the research design: explanatory measures are lacking; impact measures are lacking; and analytic techniques are misused.

RESEARCH DESIGN IS LACKING

In each of the five elements of research design, the Evaluation Sample projects exhibit major problems which limit the validity of their reported impact results: test hypotheses are not specific; randomization/control schemes are inappropriate; measures frameworks are incomplete; measurement methods are not explicitly stated and analytic techniques are not clearly defined.

Test Hypotheses Are Not Specific

With the exceptions of Kansas City, New Orleans and Portland, the crime-related test hypotheses are not specific as to the kinds of crime street lights are expected to affect. The most typical hypothesis, "increased street lighting reduces crime" defines neither the "increased street lighting" level nor the "reduced crime" level.

Similarly, except for Kansas City and Portland, the criteria for determining the occurrence of specific types of crime displacement are not given by the Evaluation Sample's test hypotheses. Additionally, among the few test hypotheses addressing attitudes and/or behavior, operational definitions of "reduced fear" and "increased police effectiveness" are not incorporated.

Randomization/Control Schemes Are Inappropriate

The predominant schemes for defining the control areas used in the Evaluation Sample (i.e., adjacent areas or the citywide area) are inappropriate. Although convenient for data collection purposes, these definitions are *arbitrary*, and the evaluations seldom give evidence that the assumed similarity between control target areas has been verified.

In fact, in two cases--Kansas City and Portland--where some care was exercised in matching target and control areas along socio-economic and demographic dimensions, the resulting areas' *crime* patterns are not comparable. In Kansas City, for example, over the one-year period prior to relighting, night street robbery increased 34 percent in the target area and decreased 31 percent in the control area.

Measures Frameworks Are Incomplete

The absence of well-defined explanatory (i.e., input and process) and impact measures has been discussed in Section 4.1. More explicit methodological problems with the individual measures are addressed elsewhere in this section.

Measurement Methods Are Not Explicitly Stated

The failure of most evaluations to report specifically on measurement methods also raises questions as to the accuracy of the resulting data.

As noted in Section 4.1, the few attitude and behavior study response rates quoted were below 50 percent. To the extent that non-respondents differ from respondents, the estimates from the samples are bound to differ somewhat from the true population figures. The *direction* and *magnitude* of the differences, however, cannot be estimated from the data given.

Similarly, virtually nothing is reported as to methods of collecting and verifying reported crime data. The two evaluations--Kansas City and New Orleans--reporting a check for errors, do not give information on the error rate.

Analytic Techniques Are Not Clearly Defined

In actual practice, the most commonly used analytic technique (i.e., before/after analysis) is sometimes not defined in regard to periods, areas or measures of comparison. Even those evaluations which do define their analytic procedures more clearly, are not explicit enough so as to enable verification of conclusions or replication of the research design. Some *misuses* of analytic techniques are highlighted separately below.

EXPLANATORY MEASURES ARE LACKING

In this subsection, two shortcomings in the explanatory measures are highlighted. First, explicit light measures are not available. Second, detailed input and process descriptions are not available.

Explicit Light Measures Are Not Available

As noted in Section 2.2, the conventional light measurements (i.e., horizontal illumination and uniformity ratio) are rarely made. In fact, in the only case--Kansas City--where illumination was measured over the entire target and control areas, the resultant data were *not* used in the evaluation. Only one evaluation--Norfolk--explicitly measured and used light data, and in this case measures were required only for a small number of target and control area blocks.

The Evaluation Sample projects provide a good illustration of how the use of a relit/non-relit dichotomy, as a substitute for explicit light measures, *obscures* both before/after and target/control area comparisons. Moreover, it is almost impossible to perform inter-project comparisons, since one project's relit area *could be* equivalent to another project's non-relit area. For example, relighting in Portland was primarily to "fill in" dark spots, which is probably the reason target area residents were mostly unaware of their area being relit. Similarly, in Kansas City, nearly 20 percent of the "relit" blocks were only partially relit as a result of a definition which classified blocks as relit if *at least* one block face or corner had received new street lights.

As discussed in Section 2.2, it is conceivable that actual field measurements of light output might not even be needed if available system descriptions are sufficiently complete to permit calculation of pertinent light measures. However, the Evaluation Sample projects do not provide adequate system descriptions, limiting their information, for the most part, to the type and size of the light source.

Detailed Input and Process Descriptions Are Not Available

The problem just discussed is an important example of a much larger problem. Because detailed input and process descriptions are not available, it is not possible either to *explain* a single project's impact, or non-impact, or to *interpret* the overall significance of the sometimes conflicting results reported by the Evaluation Sample.

Although many explanatory variables go unreported in the Evaluation Sample, perhaps the most obvious problems come from the lack of descriptions of concurrent programs. Among concurrent law enforcement programs, police patrol experiments and police manpower increases took place in Denver, Kansas City, Newark, Richmond and Washington, D.C., all overlapping their respective street lighting projects in both time and space. Still other types of law enforcement programs overlapped street lighting projects in those cities--Atlanta, Baltimore, Denver, Newark and Portland--which were part of the LEAA High-Impact Anti-Crime Program. Several other cities had overlapping physical and social programs, including Urban Renewal (Norfolk) and Model Cities (Tucson) programs. Although some of these evaluations give general descriptions of concurrent programs, none is detailed enough to permit identification of their direct impact or their possible synergistic interactions with street lighting.

IMPACT MEASURES ARE LACKING

As in the case of the explanatory measures, the impact measures are also lacking. More specifically, the attitude and behavior measures are problematic, and the crime measures are inappropriate.

Attitude and Behavior Measures Are Problematic

In perusing the questionnaires that are included in the evaluations which undertook attitude and behavior surveys, some typical survey research problems are evident. Some questions are unclear, while others are leading or biased. Additionally, in the case of street lights where there are physical elements involved, some responses may be biased by the respondents' attitude to the aesthetic properties of the lights. Thus, a respondent who likes the street lights may intentionally give positive answers to all questions regarding the lights' effectiveness.

The use, in Newark, of arrest level and clearance rate as measures of police patrol effectiveness is, for several reasons, an unsatisfactory measure of street lighting impact. First, these measures are highly dependent on other factors, such as police patrol methods, police investigative procedures and police management decisions. Second, Newark uses the total figures for these measures, which combine the night and day statistics.

Crime Measures Are Inappropriate

The Kansas City evaluation found the night/day and street/non-street breakdowns, and their combinations, to be useful in its analysis of crime. Unfortunately, the majority of the evaluations do not have similar breakdowns. Certainly, the use of a total crime statistic, without breaking it down by crime type, night/day and street/non-street categories, is inappropriate, at best. This problem is actually a reflection of the inadequacy of the research design, which, as shown in Exhibit 4.3, usually states a test hypothesis in terms of "reduced crime," without further detailing the nature of the crime.

ANALYTIC TECHNIQUES ARE MISUSED

In this subsection, the primary analytic technique employed by the Evaluation Sample (i.e., before/after analysis) is reviewed from a critical perspective to identify certain methodological problems which undermine the significance of some of the impact results. Analytic techniques are also discussed in Section 5.3, but there the perspective is more prescriptive, focusing on ways of avoiding the pitfalls that are identified in this subsection. In the present discussion, the problems addressed include the fact that statistical significance tests of reported impacts are minimal and the determination that statistical analyses are sometimes invalidated by unwarranted stability assumptions.

Statistical Significance Tests Are Minimal

In many of the Evaluation Sample projects--Baltimore, Chicago, Harrisburg, Miami, Milwaukee, Newark, Richmond and Washington, D.C.--the impact results are presented without any analysis of their statistical significance.

Among studies of attitude and behavior--except for Norfolk and Portland--tabulation of survey results is made without even stating the confidence interval within which the results are reliable estimates of the true values.

Statistical significance tests are also not performed in those evaluations which address crime impacts. If these tests were performed one might hypothesize that several of the inconsistent impact results that are discussed in Section 4.3 would not be present.

Statistical Analyses Are Sometimes Invalid

Most of the statistical analyses that are invalid are caused by unwarranted stability assumptions. As examples, two invalid analyses in the Atlanta and Kansas City evaluations, respectively, are critically reviewed.

Atlanta Analysis

Atlanta used a chi-square test to assess whether night robbery had changed significantly in a relit district (i.e., in a before/after test with no control area). In the four three-month periods preceding the relighting, the numbers of night robberies were 6, 6, 8, 6, respectively. In the three months after the new lights appeared, there were 12 robberies. The null or test hypothesis was that the robbery level per month was *constant* over the five three-month periods and that the observed differences were just random fluctuations. Application of the chi-square test to the test hypothesis yielded the conclusion that, at a .05 level of significance, the observed variation or change in robbery level was consistent with chance. In short, a virtual doubling of night robbery after the relighting was dismissed as a chance phenomenon.

Actually, however, the result was overstated, caused by the fact that the test hypothesis was a combination of two separate hypotheses:

a) there were no *seasonal* effects in robbery levels, and b) robbery after the installation remained at its previous level. The overall chi-square statistic, which was calculated, was in some sense a "weighted average" of the consistency of these two hypotheses with the data and the seasonality hypothesis was in fact strongly supported by the pre-lighting data. Since the chi-square test either accepted both hypotheses or rejected both, this strong non-seasonality made it harder for the post-relighting variation to dominate the test.

A better approach would have been first to test the absence of seasonality by the test hypothesis that the robbery level is constant over the four *before* periods. As noted, this is easily verified by the data. Next, the hypothesis of interest is that, over the five periods, each robbery has a four-fifths chance of falling within the first four and a one-fifth chance of falling within the last. Once again, at the .05 significance level, the result is that the variation is consistent with chance, but just barely; it would not be at the .10 level.

In sum, the assumed non-seasonality of the data subjects the test of significance to a bias which, depending on the data, may act either in favor of or against the test hypothesis.

Kansas City Analysis

A somewhat different problem occurred in Kansas City where a chi-square test was applied to some simple before/after comparisons and to a series of before/after, target/control area comparisons.

In the first step of the analysis, comparisons were made within the target area using data from a *baseline* period (i.e., two comparable nine-month periods before the relighting) and a *test* period (i.e., two one-year periods just before and just after the relighting). In these comparisons, the night street robbery in the target area increased by 34 percent (i.e., from 35 to 47) in the baseline period, while it decreased by 52 percent (i.e., from 67 to 32) in the test period. In the second step of the analysis, Kansas City compared the target and control areas on a before/after basis, using *test* period data. Thus, following relighting, the night street robbery in the target area decreased by 52 percent (i.e., from 67 to 32), while in the control area it decreased only 17 percent (i.e., from 89 to 74).

It should be noted that the above-described analysis does not take into consideration the underlying random fluctuations which may exist in the data points. Assuming that the same fluctuation affects both the target and control areas, a more meaningful statistic for comparison purposes would be the ratio of night street robberies in the target area to that in both the target and control areas. Using the statistic, it is seen that, following relighting (i.e., during the test period), the target area's share of night street robbery did indeed decrease (i.e., from 67/(67+89), or 43 percent, to 32/(32+74), or 30 percent). However, an equally significant *increase* (i.e., from 35/(35+91), or 28 percent, to 47/(47+63), or 43 percent) in the target area's share occurred during the baseline period, when there was no street lighting intervention. This apparent regression artifact is also present in the analyses of some other target crimes for which Kansas City has reported significant street lighting impacts. Moreover, the above analyses also *question* the comparability of the target and control areas which were selected for the study.

4.3 IMPACT RESULTS

Based on the foregoing review of research designs and methodological problems, a critical assessment of the reported impacts of the Evaluation Sample is undertaken in this section, and a judgement is made as to the current state of knowledge regarding the impact of street lighting on crime. More specifically, three general conclusions are noted. First, there are strong indications that, following increases in street lighting, the fear of crime is reduced. Second, there is some indication that, all other things being equal, feelings of safety are higher in those night street environments which have more uniform lighting levels. Third, reported impacts on crime are inconclusive.

These conclusions must, of course, be accepted with caution since they are primarily based on the 15 Evaluation Sample projects, which, as noted in Sections 4.1 and 4.2, have considerable research design and methodological problems. In fact, in several cases, the projects themselves do not summarize their own conclusions, leaving it up to the reader to interpret what sometimes amounts to raw data. Nevertheless, Exhibit 4.4 attempts to summarize the reported impacts and their reported statistical significance. The remainder of this section considers the attitude, behavior and crime impacts in more detail.

Exhibit 4.4

Evaluation Sample: Reported Impacts

City	Reported Impacts[1] Attributed to Street Lighting			Statistical Significance of Results	
	Attitude	Behavior	Crime	Reported Significance	Methodological Problems[2]
Atlanta, GA	• Not addressed	• Not addressed	• Reported night Part I crimes increased in target and control area • No change in ratio of night to total Part I crime	• Not significant (lack of significance attributed to small data base)	• RD, EM, AT
Baltimore, MD	• 66% of residents "feel safer"	• 14% of residents "go out at night" more often	• Reported night street robbery increased by 44% in one year • Reported rape decreased by 21% in one year • Reported residential burglary increased (time of day not stated)	• Not stated	• RD, EM, IM, AT
Chicago, IL	• Not addressed	• Not addressed	• Reported citywide night Index crime decreased 2.7% in one year; reported night Non-Index crime decreased 12.2% in one year	• Not stated	• RD, EM, AT
Denver, CO	• 43% of residents were unaware of "additional" street lighting • Of residents aware of street lighting improvement, over 67% "feel much safer"	• Of residents aware of street lighting improvement, 18% "observed crime in progress...(and) reported to the police", and 18% "walk in neighborhood at night" more often	• Reported night violent Part I crime decreased by 11.8% in 10 months	• Attitude and Behavior: not stated • Crime: not significant (lack of significance attributed to small data base)	• EM, IM, AT
Harrisburg, PA	• Residents and foot patrolmen "feel safer" • Business owners felt their establishments were "more secure" • Residents and business owners preferred new street lights (i.e., high-pressure sodium) to old (i.e., mercury vapor)	• Foot patrolmen reported street lighting to be an "effective aid in their performance"	• No impact on reported night robbery, assault, burglary or auto theft	• Not stated	• RD, EM, IM, AT

[1]Unless otherwise stated, the reported impacts refer to target area impacts on a before/after comparison basis.

[2]RD: research design is lacking; EM: explanatory measures are lacking; IM: impact measures are lacking; AT: analytic techniques are misused. These problems are discussed in Section 4.3.

Exhibit 4.4

(page 2 of 3)

City	Reported Impacts[1] Attributed to Street Lighting			Statistical Significance of Results	
	Attitude	Behavior	Crime	Reported Significance	Methodological Problems[2]
Kansas City, MO	• Not addressed	• Not addressed	• Reported night street robbery and assault were decreased by 52% and 41%, respectively • No impact on reported night street crimes against property--burglary, larceny and auto theft • From $^1/_4$ to $^1/_3$ of "prevented" night street robberies were displaced to adjacent nonrelit blocks	• Significant at .05 level • Not significant at .10 level • Not stated	• RD, EM, AT
Miami, FL	• Not addressed	• Not addressed	• Reported night crimes against person decreased twice as much in target area as in entire city, in one year • No impact on reported night crimes against property	• Not stated • Not stated	• RD, EM, AT
Milwaukee, WI	• 82% of residents "feel safer" • 71% of residents perceived decrease in crime • 90% of residents were "generally satisfied"	• 52% of residents "go out more" at night • 88% of police report "patrol more efficient" • 44% of police report lights "assist in apprehending"	• No impact on reported night crimes against person • Reported auto theft increased one year after relighting • Other reported crimes against property decreased	• Attitude: not stated • Crime: "not conclusive" (attributed to small data base)	• RD, EM, IM, AT
Newark, NJ	• Not addressed	• Part I crime arrests increased by 98% and Part I crime clearance rate increased by 24% in one year	• Reported Part I crime decreased by 20% in one year in target area, compared with a citywide increase of 14%	• Not explicitly stated, but evaluation notes that crime decrease can be attributed only to *combined* street lighting and team policing experiment	• RD, EM, IM, AT
New Orleans	• Not addressed	• Not addressed	• No impact on reported night business burglary, assault or auto theft	• Not explicitly stated, but time series analysis implies no significant impact	• EM, AT

Exhibit 4.4
(page 3 of 3)

City	Reported Impacts[1] Attributed to Street Lighting			Statistical Significance of Results	
	Attitude	Behavior	Crime	Reported Significance	Methodological Problems[2]
Norfolk, VA	• Street lighting systems with relatively higher uniformity, lower illumination, fewer shadows and lower color temperature increased test subjects' overall rating and sense of security	• Factors limiting night street use included "sense that streets are not secure"; "fear of kinds of people you meet"; and "insufficient lighting"	• Not addressed	• Not explicitly stated, but interpretation of multiple regression results implies statistical significance	• IM
Portland, OR	• 25% of target area residents were aware of increased street lighting • No impact on residents' feelings of safety • Citywide, the association between perception of and actual street lighting quantity was "not very strong"	• Not addressed	• No impact on reported night robbery, assault or burglary	• Attitude: not explicitly stated, but analysis of association among survey responses implies statistical significance of reported non-impacts • Crime: not significant at .05 level	• RD, EM, IM
Richmond, VA	• Not addressed	• Not addressed	• Reported residential burglary increased by 7% and reported non-residential burglary decreased by 28% in one year	• Not stated	• RD, EM, IM, AT
Tucson, AZ	• Residents felt "substantially safer", and reported "less fear" walking through alleys at night	• Not addressed	• No impact on total reported Part I crime	• Not stated	• EM, IM, AT
Washington, D.C.	• Not addressed	• Not addressed	• Reported night robbery, residential burglary, auto theft and vandalism decreased by 65%, 44%, 56%, and 22%, respectively, in two years	• Not stated	• RD, EM, AT

ATTITUDE IMPACTS

Among the tabulated attitude survey results, the most consistent result was that residents and police reported "feeling safer" after the installation of street lights. With the exception of Portland, where only 42 percent reported feeling somewhat or much safer,* the fraction of respondents answering positively to this type of question ranged from 66 to 82 percent. Additionally, in the Harrisburg survey, 88 percent of business owners said that their establishments were "more secure" as a result of street lighting. From 88 to 100 percent of residents and business owners also reported in three surveys that they were "generally satisfied," or that they "preferred the new lights to the old."

In the Norfolk project, all, but one, of the environments which were rated as "secure" belonged to the target area, where there was lower illumination level, higher illumination uniformity and fewer shadows, relative to the more conventionally designed control area. When the target area illumination was artificially reduced, while maintaining *uniformity*, ratings of security did not decrease.

Also in Norfolk, a complex series of regression analyses resulted in a Security Index (i.e., a measure of the sense of security) which is explained by the following relation:

$$SI = .72H + .45W + 1.05V - .08,$$

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* However, this result is based only on the 25 percent of the Portland respondents who indicated that they were aware of the existence of new lights.

where H is the illumination uniformity ratio on the sidewalk, W is a dimensionless index of "relative wealth" of the area (with values ranging from 0 to 1) and V is the average vertical illumination on the sidewalk. The study notes, however, that the validity of this relationship has been established only for values of V below 0.4 footcandles and values of W above 0.2.

Despite the problems noted in Section 4.2, the Evaluation Sample's reported impacts on attitude are quite consistent. However, because all of the surveys took place within a year of the street lighting installation, the long-term *stability* of this conclusion cannot be assumed. Also, because of the absence of any analysis of statistical significance, there are *strong* indications, although not conclusive proof, that the fear of crime is reduced following increases in street lighting.

Finally, based upon the Norfolk project, there is an indication that lighting uniformity is a key factor in the determination of an individual's sense of security.* While the Norfolk evaluation appears to be methodologically sound, it is unique and should be replicated elsewhere.

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*Although no extensive study was conducted, the City of Las Vegas, Nevada, found that its downtown street lighting needed upgrading along the side streets, bordering the major boulevards, because pedestrians were fearful of the perceived darkness in those streets. A visual inspection of the downtown area revealed that the problem was really due to the non-uniformity of the lighting levels: the boulevards are very brightly lit especially in comparison to the side streets, and yet the lighting level on the side streets is typical of that found in most U.S. cities.

BEHAVIOR IMPACTS

Tabulated survey data on reported changes in behavior reveals that from 14 percent--in Baltimore--to 52 percent--in Milwaukee--of the respondents reported going out more at night since installation of the new street lights. In Denver, 18 percent of those aware of the street lighting project said that the street lights had helped them to observe and to report to the police a crime in progress.

Virtually all of the police officers patrolling in the relit area of Harrisburg reported that the new street lighting improved their reaction time, distance visibility, and ability to cover fellow officers and to identify suspects. In Milwaukee, 88 percent of the officers said that the new lighting made their patrol "more efficient," and 44 percent reported that the lights had helped them apprehend suspects.

While none of the Evaluation Sample projects addresses which aspects of the new street lights were responsible for the self-reported behavior changes, the Norfolk study does probe the conditions which limit pedestrian night street use--without, however, actually measuring it. The majority--81 percent--of the Norfolk test subjects said that they used their neighborhood streets less frequently than they would like. The reasons given for not using the streets included the feeling that the streets are not secure; the fear of the kinds of people likely to be met on the streets;and the inadequacy of the street lighting illumination.

In an effort to assess changes in police effectiveness, the Newark evaluation showed that the total target area Part I crime arrests and clearance rate increased by 98 and 24 percent, respectively, in a one-year period following the relighting. However, no comparison is made with other control areas and no analysis of statistical significance is given. More importantly, the intervening effects of other factors on police effectiveness are not discussed.

Because of the problems discussed in Section 4.2 regarding self-reported changes in behavior, and arrest and clearance data, these reported impacts on behavior cannot be regarded as significant. However, it may be assumed, in light of the corroboratory attitude survey results, that the nearly unanimous responses of police officers to behavior-oriented questions is another strong indication of their *approval* of improved street lighting.

CRIME IMPACTS

All crime impacts given by the Evaluation Sample projects are based on reported crime. For each of the Part I crime types, more projects report increases, or no change, than decreases in crime. For example, in the case of robbery, two projects--Kansas City and Washington, D.C.--reported decreases, two--Harrisburg and Portland--reported no change, and one--Baltimore--reported an increase. Of these, Kansas City and Portland each said that the reported impact or non-impact was statistically significant at the .05 level, while the others did not perform any statistical significance tests. Similarly, one project--Kansas City--noted a decrease in assault, while three--Harrisburg, New Orleans and Portland--reported no change.

As noted throughout this study, inter-project comparisons are difficult to make since different projects do not make use of the same crime breakdowns (i.e., street/non-street, night/day, etc.); they do not all report on the statistical significance of the reported impacts; and they do not all consider other explanatory or intervening effects in their analysis of impact results.

Crime displacement effects are reported only in the Kansas City and Portland evaluations. Since there was no apparent impact on crime level in the Portland target area, no territorial displacement into neighboring non-relit blocks was observed there. In Kansas City, displacement from night street crime in relit blocks to night street crime in non-relit blocks, to night non-street crime in relit blocks, and to day street crime in relit blocks was measured. It was found that night street robbery, assault and larceny in residential blocks were displaced to non-relit residential blocks, retaining their night street character. The largest effect was for robbery, for which it is reported that from a fourth to a third of the night street robberies prevented were displaced to non-relit blocks.

Again, because of the methodological problems discussed in Section 4.2 and the contradicting results noted above, the reported impacts on crime must be regarded as *inconclusive*.

5 SINGLE PROJECT EVALUATION DESIGN

The conduct of an evaluation frequently presents problems both to the evaluator and the staff of the project being evaluated, resulting in evaluation findings that may be limited in both validity and relevance. One problem is the apprehension on the part of the project staff on being "evaluated." The apprehension can be mitigated by clarifying the purpose of the evaluation--namely, to assess the effectiveness of the total project rather than the work performed by the individual project staff members. A second problem arises because the role of an evaluator is not well defined. In addition to performing an evaluation or summary judgement at the *end* of the project, the evaluator could also assist *during* the project by periodically providing evaluation-related data to the project managers so that they could *monitor* the progress of the project. It should be noted that this dual use of evaluation-related data would in no way compromise the evaluator's objectivity; it simply minimizes the cost of data collection.

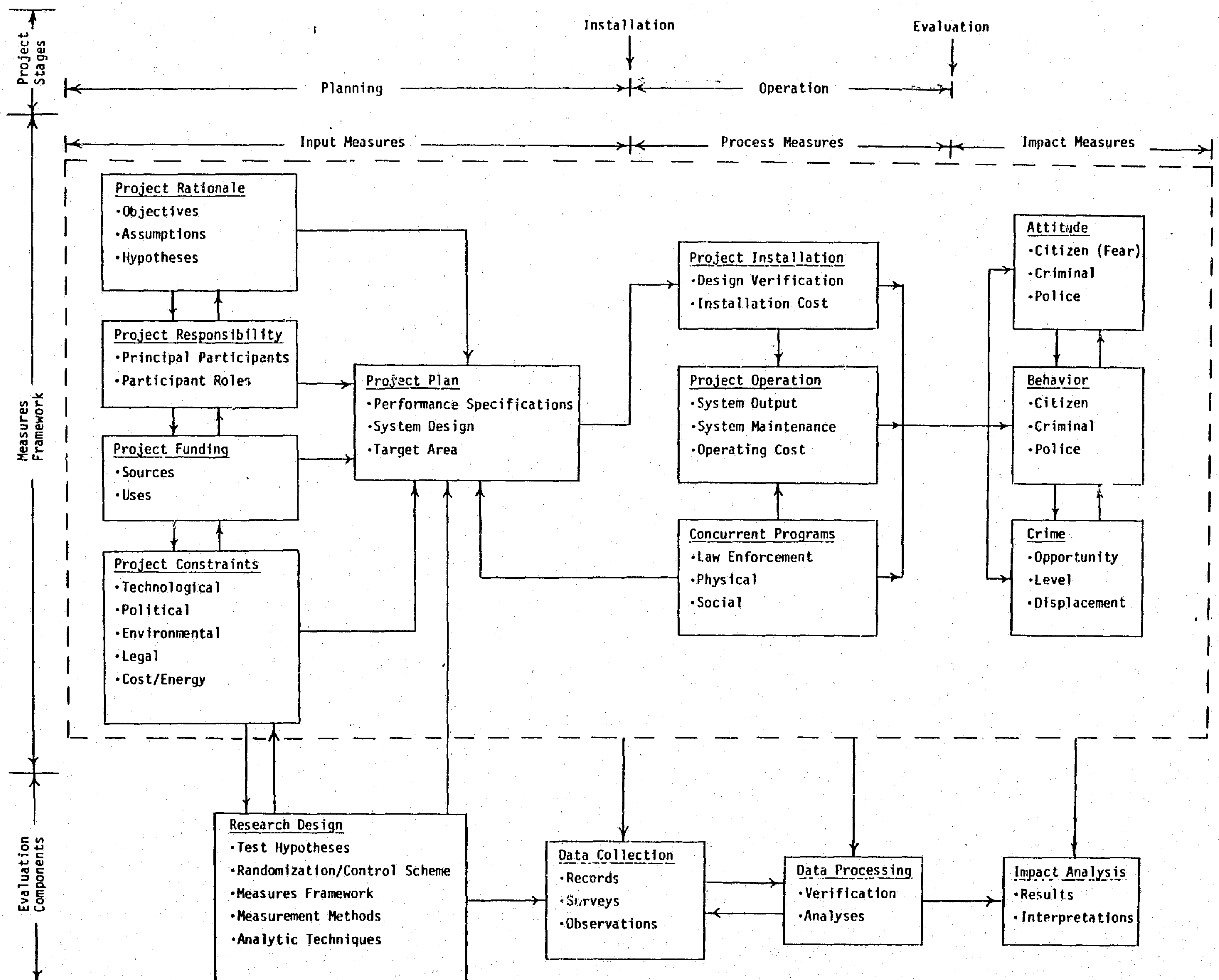
A potential third problem regarding the need to collect evaluation-related data can be overcome if an evaluation design is developed and implemented at the same time that the project is implemented. In order to minimize this problem in future street lighting evaluations, a street lighting-related single project evaluation design is identified in this section. As indicated in Exhibit 3.1, the design is the result of applying the single project evaluation framework--identified in Section 3.2--to a "typical" street lighting project. The typical project is assumed to have the characteristics of the various projects discussed in Sections 2 and 4. However, because the characterization of such a project cannot be detailed enough to include, for example, political and funding constraints, the design contained herein should be regarded as somewhat general and in *need* of refinement.

The single project evaluation design is illustrated in Exhibit 5.1. It is seen that the evaluation requirements of Exhibit 3.2 are expressed in the *measures framework* as a set of input, process and impact measures, which span the project stages from planning through evaluation. The *evaluation components* are shown in the third level of Exhibit 5.1 in relation to the entire measures framework. The end product of the evaluation (i.e., the final component) is the *impact analysis*, which consists not only of evaluation results, but also of interpretations of those results. The *interpretation* of results is stressed because evaluation, especially of social programs, is not an exact science. Although many potential explanatory measures are available only in qualitative form and existing analytic techniques are limited, the significance of an evaluation's results would be better understood if the potential contribution of all relevant explanatory measures were addressed.

The remainder of this section describes, in turn, the measures framework, the evaluation components and the analytic techniques of a street lighting evaluation design. A somewhat detailed description

Exhibit 5.1

Single Project Evaluation Design



of analytic techniques is given in Section 5.3, because of the need to highlight certain problems which arise in connection with their application in the topic area of street lighting and crime.

5.1 MEASURES FRAMEWORK

The input, process and impact measures--which constitute the measures framework--are defined and briefly discussed in Exhibits 5.2, 5.3 and 5.4, respectively. Except where noted in the remarks of the respective exhibits, the information specified by these measures is generally available, although, as pointed out in Section 2.1, not usually in one location.

The exhibits are self-explanatory. Two issues, however, require clarification. The first is the relation between the measures framework and test hypotheses; and the second concerns the interactions among the measures.

RELATIONSHIP TO TEST HYPOTHESES

Exhibits 5.2 and 5.3 call for a large number of input and process measures to be collected as part of the measures framework requirements. Given the focus of the topic area--which hypothesizes that light output impacts crime--it may be asked: What is the purpose of such an extensive data base? The answer is that the input and process measures are not only needed to test the stated hypotheses, but also to "explain" the resultant tests. The failure of most Evaluation Sample projects to view their findings in terms of this broader perspective has cast doubt on the validity and usefulness of the findings.

Exhibit 5.2

Measures Framework: Input Measures

Purpose	Categories	Measures [Remarks]
• Project Rationale	• Objectives	• Determine stated objectives in quantitative and/or qualitative form. [Note whether different statements are made by different participants:]
	• Assumptions	• Determine assumptions used in arriving at stated objectives. [Determine, if possible, which aspects of street lighting, and which intermediate and concurrent events, are assumed to result in specified impacts.]
	• Hypotheses	• Determine which hypotheses the participants intend to test. [Hypotheses should be stated in terms of measurable elements; compound chains of events should be broken into simple cause-effect links.]
• Project Responsibility	• Principal Participants	• Identify participants, including public officials; engineering departments; utility companies; law enforcement/criminal justice agencies; planning and development agencies; public property departments; administrative services departments; and other private sector participants.
	• Participant Roles	• Identify roles to be played by each participant in the planning, installation, operation and evaluation stages of the project.
• Project Funding	• Sources	• Type and mandate of each funding source, including any restrictions. • Amount of federal and local funds, by project or budget item.
	• Uses	• Total funds used for *initial cost* items (i.e., engineering, purchase and installation of equipment, and utility penalty charges) and for *annual operating cost* items (i.e., energy, maintenance and utility company lease charges). [Identify uses of funds by funding source.]
• Project Constraints	• Technological	• Constraints on system design or target location attributed to technological factors (e.g., equipment availability from manufacturers; existing wiring not compatible with high-pressure sodium light source; existing pole heights not compatible with desired lumen output, etc.).
	• Political	• Constraints on system design or target location attributed to political decisions (e.g., requirement for or exclusion of high-pressure sodium light source by mayor; specific areas "promised" street lighting during election campaign, etc.).
	• Environmental	• Constraints on system design or target location attributed to environmental factors (e.g., utility company guidelines; preservation of trees or architectural standards; crime prevention through environmental design requirements; etc.).
	• Legal	• Constraints on system design or target location attributed to legal factors (e.g., municipal ordinance(s) requiring or regulating private property lighting; court judgements establishing municipal liability in street lighting-related cases of crime incidence; etc.).
	• Cost/Energy	• Constraints on system design attributed to total cost or to energy cost and availability. [Determine rationale used, including design tradeoffs made, if any.]

Exhibit 5.2
(page 2 of 2)

Purpose	Categories	Measures [Remarks]
• Project Plan	• Performance Specifications	• Technical specifications, including average horizontal illumination, illumination uniformity, roadway/walkway luminance, glare, etc. for *vehicular roadways* and *pedestrian walkways*. [Compare with IES performance specifications--note that the IES specifications are expected to be revised in 1977.]
		• Management specifications: project budget and schedule.
	• System Design	• Number and location of street lights. [Determine these measures for both the old and the new system.]
		• For each street light: light source type (i.e., high-pressure sodium, mercury vapor, etc.), wattage and initial lumen output; luminaire light distribution patterns; glare characteristics (i.e., full-, semi- or non-cutoff), and photometric data (supplied by manufacturers); pole mounting height, spacing and configuration, and bracket overhang; wiring type (i.e., overhead, underground; series, parallel). [Determine these measures for both the old and the new system.]
	• Target Area	• Selection criteria (e.g., high-crime, traffic safety, other program links, natural boundaries, political factors, technological factors, etc.) and decision-making process.
		• Target area boundaries and area in terms of number of street miles or number of blocks.
		• Land use (i.e., residential, commercial, industrial, etc.). [Note day/night land use *differences*.]
		• Environmental conditions, including classification and condition of streets and alleys; structural conditions of buildings; opportunities for concealment and surveillance; and distribution of targets. [Measures relevant to the proper design and effective use of the built environment are being developed and tested as part of the LEAA-funded Crime Prevention Through Environmental Design Program.]
		• Social indicators, including demographic and socioeconomic variables and trends.

Exhibit 5.3

Measures Framework: Process Measures

Purpose	Categories	Measures [Remarks]
• Project Installation	• Design Verification	• Procedures used to verify system design after installation. • Modifications, if any, to system design. • Problems encountered during installation; steps taken to resolve problems; and any resultant delays.
	• Installation Costs	• Final cost for engineering; purchase and installation of equipment; and utility company penalty charges.
• Project Operation	• System Output	• Procedures used to verify performance specifications, and compare with the IES-recommended procedures. • Instrumentation used to verify performance (i.e., model number, manufacturer, filters, etc.). • Deviations from indicated performance specifications, and reasons for such deviations. • Energy-related changes, including type and degree of change, (e.g., turn off street lighting, reduce lamp wattage, etc.); reason for change (e.g., cost or availability of energy); location and duration of change; and reason for resumption, if any, of normal output. [Energy-related changes may result in "natural experiments" which could be analyzed to test the impact of street lighting on crime.]
	• System Maintenance	• Schedule and procedures for cleaning luminaires and replacing lamps.
	• Operating Cost	• Annual utility company lease rate (i.e., for utility-owned systems), or annual energy, maintenance and amortization of initial costs (i.e., for municipally-owned systems). [Both project total and unit cost (i.e., cost by type and size of street light) should be obtained.]
• Concurrent Programs	• Law Enforcement	• Changes in police patrol *tactics*, including target area(s), dates, and tactical changes (e.g., preventive patrol experiment, high-visibility patrol, split force patrol, etc.). [Any available measures of police patrol effectiveness made in connection with tactical changes should be obtained.] • Changes in police patrol *level*, including target area(s), dates, and degree of change. • Other crime prevention or Crime Prevention Through Environmental Design programs, including target area(s), dates, and activities.
	• Physical	• Other street lighting projects, including target area(s), dates, type and size of light source. • Tree pruning activities, including target area(s) and dates. • Street reconstruction or street furnishing programs, including target area(s), dates, and activities. • Housing or other building construction, rehabilitation or demolition, including target area(s), dates, and activities.
	• Social	• Employment, youth activities, drug treatment programs, etc., including target area(s), target population, dates, and activities.

Exhibit 5.4

Measures Framework: Impact Measures

Purpose	Categories	Measures [Remarks]
• Attitude[1]	• Citizen[2]	• Measure of citizens' fear of crime. [Such measures are still lacking and in need of testing and refinement.] • *Proxy* measures for fear of crime or change in fear of crime include perceived crime rate change; perceived light quantity or quality; perceived change in number of night street users; perceived police effectiveness; and citizens' target hardening actions. [Questions measuring reported changes in fear or proxies for fear should not use street lighting as the reference event, because other attitudes about street lighting may bias the responses.] • Citizens' overall rating of street lighting (i.e., brightness, glare, warmth, uniformity, color rendition, appropriateness and desirability). • Reported barriers to use of streets at night.
	• Criminal	• Measures of criminals' perception of own conspicuousness, risk and vulnerability. [Such measures are still lacking and in need of testing and refinement. Interviews of criminals who have been incarcerated may bias survey results. In addition, a specific environmental reference is required, which may require conducting interviews with slides of different night street environments.]
	• Police	• Measures of police officers' fear of crime, particularly of assault. [Such measures are still lacking and in need of testing and refinement.] • Police officers' overall rating of impacts of street lighting on job performance (e.g., ability to detect, recognize, identify and apprehend offenders; ease of night street patrolling, etc.).
• Behavior	• Citizen	• Citizens' reported frequency, purposes and tactics of own night street use. • Night pedestrian volume. [Sampling should take into account cyclical variations and weather patterns.] • Commercial area business activity. [Sampling should take into account cyclical variations, weather patterns, and economic conditions.] • Measures of citizens' ability to detect, recognize, identify and evade criminals on the street at night. [Such measures are still lacking and in need of testing and refinement.]
	• Criminal	• Police officers' reported changes in criminals' tactics. • Measures of criminals' changes or displacement in offense times, territory, tactics, targets and crime type. [Such measures are still lacking and in need of testing and refinement. Interviews of criminals who have been incarcerated may bias survey results. In addition, a specific environmental reference is required, which may require conducting interviews with slides of different night street environments.]

[1] Reported changes in attitudes measured by a single survey (e.g., "are you more afraid now?") require careful selection of a reference event or time (e.g., "since street lighting was increased" or "since one year ago"). Also, absolute-value measures of attitudes (e.g., semantic differential scales) enable changes to be measured directly by successive surveys, and enable differences between street lighting and control areas to be measured.

[2] Citizens include residents as well as other night street users (e.g., business patrons and employees, or persons passing through target area).

Exhibit 5.4

(page 2 of 2)

Purpose	Categories	Measures [Remarks]
• Behavior (continued)	• Police	• Police officers' reported changes in own tactics. • Arrests per patrol officer for each night street Part I crime. [Interpretation of arrest rate as a measure of police *effectiveness* requires careful consideration of other factors (e.g., arrest quotas, quality of arrest, etc.).] • Clearance rates per patrol officer for each night street Part I crime. [Interpretation of clearance rate as a measure of police *effectiveness* requires careful consideration of other factors (e.g., crime recording practices, changes in crime reporting rate, investigative practices, etc.).]
• Crime	• Opportunity	• Measures of crime opportunity. [Such measures are still lacking and in need of testing and refinement.]
	• Level	• Reported night street Part I crime data. [Despite problems of accuracy and classification, reported crime rate data are readily available at little cost. For some analytic techniques, day street, night non-street and day non-street Part I crime data are also required. As much detail as possible should be obtained (e.g., block face or other geocodable location index, exact time of day, type of premises, modus operandi, etc.).] • Victimization rate for each night street Part I crime. [Although expensive, victimization surveys provide a more accurate measure of crime occurrence than reported crime. For some analytic techniques, day street, night non-street and day non-street Part I crime victimization rates are also required. More subjective data can also be gathered in victimization survey.]
	• Displacement	• Reported Part I crime data. [Each crime should be categorized by time of day, location of occurrence, tactic used, type of target and crime type.] • Victimization rate for each Part I crime. [Each crime should be categorized by time of day, location of occurrence, tactic used, type of target and crime type.]

The relation between the measures framework and test hypotheses is illustrated in Exhibit 5.5, which identifies six tested--based on the Evaluation Sample projects--hypotheses in terms of links between the explanatory and impact measures. It is noted in Exhibit 5.5 that only one category of explanatory measures--light output measure, within project operation--has been explicitly tested for its *direct* effect on impact measures. A second category--concurrent programs--is also emphasized in Exhibit 5.5 because its measures are assumed by some programs (i.e., the Crime Prevention Through Environment Design--CPTED-- programs) to have a supportive or *synergistic* effect, along with light output, on the impact measures. However, as indicated in Exhibit 5.5, the synergistic test hypotheses have not yet been tested. In fact, the large number of empty cells in the Exhibit 5.5 matrix highlights the *paucity* of tested hypotheses.

INTERACTIONS AMONG MEASURES

Street lighting input measures should be collected with the awareness that there are interactions among them, especially during the project planning stage. For example, the identification of an environmental constraint may result in a change in the system design or target area.

In fact, the first four groups of input measures (i.e., project rationale, project responsibility, project funding and project constraints) not only interact with each other, as shown in Exhibit 5.1, but, as a group, with the evaluation's research design. Not only do these input considerations establish a set of constraints on

CONTINUED

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Exhibit 5.5

Measures Framework: Tested Hypotheses[1]

Explanatory Measures	Impact Measures								
	Attitude			Behavior			Crime		
	Citizen	Criminal	Police	Citizen	Criminal	Police	Opportunity	Level	Displacement
Project Rationale									
Project Responsibility									
Project Funding									
Project Constraints									
Project Plan									
Project Installation									
Project Operation[2]	H_1, H_2		H_1	H_3		H_4		H_5	H_6
Concurrent Programs[2]									

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[1] Tested hypotheses include H_1: "Increased street lighting reduces fear of crime"; H_2: "Street lighting uniformity and illumination together reduce fear of crime"; H_3: "Increased street lighting increases night street use"; H_4: "Increased street lighting increases police effectiveness"; H_5: "Increased street lighting reduces crime"; H_6: "Increased street lighting displaces crime."

[2] The project operation--specifically, light output--and the concurrent programs--specifically, specialized police patrol methods--are usually assumed to have a *direct* or *synergistic* effect on the impact measures. Other explanatory measures are assumed to have an indirect, intervening effect on the impact measures.

the research design, but the requirements of the research design itself must be taken into account while the project plan is being developed, in order to *assure* the feasibility of the evaluation.

Interactions among the impact variables are less well understood. In linking night street use and crime (i.e., a behavior-crime interaction), for example, it has been conjectured that the distribution of night street crimes against person, as a function of pedestrian density, is two-tailed [A.2-2]. That is, on the one hand, when there are no people on the street to be victimized, there can be no crimes against person; and, on the other hand, as pedestrian traffic increases, it is speculated that crime incidence increases until a threshold level of traffic is reached, after which crime would be deterred by the increased presence of witnesses and potential intervenors.

Similar speculations can be made about attitude-behavior and attitude-crime interactions. For example, most research on the subject would argue that the fear of predatory stranger-to-stranger crimes roughly correlates with their rates of occurrence (i.e., in high crime neighborhoods there is high fear). However, crime and fear are *not* synonymous. In general, such interactions are not well understood and their study requires consideration of a great many factors beyond the scope of this single project evaluation design.

5.2 EVALUATION COMPONENTS

The evaluation components, as indicated in Exhibit 5.1, consist of research design, data collection, data processing and impact analysis. Each of these components is discussed in turn in this section.

In understanding the material in this section, it is important to realize that the experimental subjects of a street lighting project are the *street lights* themselves. Thus, in contrast to other law enforcement programs where the experimental subjects are usually a group of people being treated (e.g., a group of defendants released on recognizance, a group of police officers on special patrol, etc.), the subjects here are inanimate fixtures. Consequently, in a street lighting evaluation, it is not possible to use flow diagrams--which characterize the flow of subjects through a system. This distinction should clarify a number of key differences between the evaluation of street lighting projects and other law enforcement and criminal justice programs.

RESEARCH DESIGN

The research design of a project is the *plan* by which the project is to be evaluated. Each component of the research design (i.e., test hypotheses, randomization/control scheme, measures framework, measurement methods and analytic techniques) is discussed in this subsection to identify its purpose.

Test Hypotheses

A test or null hypothesis is defined as a statement--regarding the relationship between one or more variables--which requires testing with actual, real-world data. In the field of social experimentation, it is usually very difficult, if not impossible, to prove the validity of a test hypothesis. On the other hand, if the hypothesis is *not* rejected after several independent tests, then a powerful argument could be made for its acceptance. Consequently, an evaluation result, which may appear inconclusive by itself, may turn out to be relevant when viewed in a larger context of comparable evaluations.

In practice, the test hypotheses are identified from the project objectives. In order to be tested, a hypothesis must a) be expressed in terms of *quantifiable* measures, b) reflect a specific relationship that is *discernible* from all other relations, and c) be amenable to the application of an available and pertinent analytic technique. Thus, for example, in a regression analysis the test hypothesis takes the form of an equation between a dependent variable and a linear combination of independent variables, while in a before/after analysis with a chi-square test, a simple test hypothesis, usually relating two variables, is used.

In the case of a complex hypothesis, it may be necessary to break it down into a series of simpler hypotheses that could each be adequately tested. As an example, the "relighting and added patrol can produce a synergistic effect" hypothesis requires the testing of five component hypotheses:

A) both improvements are together better than just more patrol;

B) both improvements together are better than just relighting;

C) both improvements together are better than nothing;

D) more patrol alone is better than nothing; and

E) relighting alone is better than nothing.

In order to test the hypotheses, and as noted in Section 3.1, the number of separate areas for which data must be obtained is 2^2, or 4 (i.e., relit with patrol; relit without patrol; non-relit with patrol; and non-relit without patrol). Based on the results of separate tests of each hypothesis, one could attempt to reach a sensible conclusion. Suppose, for instance, that one finds statistically significant support in the data for hypotheses A, C and E, but not B and D; this would suggest that the relighting is helpful, but the incremental value of the added patrol is not demonstrated. Other outcomes of the testing would have other implications. On the contrary, suppose one obtains the result that B and D are significantly supported, but A, C and E are not; that would suggest that more patrol tends to cut down crime but relighting works in the opposite way to stimulate more crime.

Randomization/Control Schemes

In an ideal experimental design situation, such as those conducted in a psychology laboratory with mice, the two most important procedures in setting up an experiment are a) selection of experimental and control groups, and b) randomization among treated population. In real-life social experiments both these procedures usually cannot be fully carried out. This is especially true for street lighting projects.

Randomization

Since, as seen in the beginning of this section, the experimental subjects are street lights, true randomization of treatment would amount to random selection of street lighting locations--and, within limits, conceivably even street lighting designs.

As the discussion in Section 2.1 makes clear, this is not generally a practical possibility, since some non-random criteria (e.g., high crime, high traffic accidents, political campaign promises, etc.) have usually to be applied. Moreover, the random installation of street lights is a very impractical and environmentally difficult process to implement. Only one street lighting project has undertaken a quasi-random approach (i.e., the Tucson two-phase plan).

Control

When, as noted above, a relit/non-relit dichotomy is required as a substitude for explicit light measures, the non-relit areas serve as control areas. However, street lighting target area selection procedures imply that some procedure other than randomization must be used for defining these control areas.

Essentially, all that is required by the various analytic techniques is that the control area facilitate prediction of what the target area impact measures would have been in the absence of the street lighting project. Unfortunately, there is no universal formula for accomplishing this target-control area equivalence. As seen in Section 4.2, for example, it is not sufficient to choose a control area solely because it has similar socio-economic indicators--crime must also be correlated.

Selection of control areas may be complicated by the possibility of a regression artifact which, as noted in Section 2.1, is likely whenever the target area is selected because of a recent high-crime incidence. To the extent that street lighting planning interacts with the research design process, it may be possible to avoid regression artifacts by the selection of target areas which have *stable,* even though high, crime incidence over a long period. In this way, areas undergoing only *short-term* upward fluctuations may be avoided, while satisfying the project planners' goal of serving areas in need. If this approach is not possible, either for policy reasons or because of the absence of any stable areas, then regression artifact can also be minimized by searching for control areas whose crime incidence bears a stable *relationship* to that of the target area. A third possible approach to minimizing the impact of a regression artifact problem is to extend the period of evaluation; this is further elaborated on in the measurement methods discussion.

It should be noted that all of the above considerations also apply to the selection of displacement areas. An additional requirement is, however, necessary; that is, a displacement area should obviously be an area where displacement is *expected* to occur. While a displacement area *may* be contiguous to the target area, it need not be. A criminal's selection of an alternative site may depend on similarity of crime targets, provision of cover by the environment, neighborhood racial composition and awareness of police tactics, among other things. In the absence of offender interviews, the best the evaluator can do is to select displacement areas on the basis of experience and logic.

Finally, another technique which could prove useful for defining control or displacement areas is the crime-correlated area model. The model postulates that the level of crime in one area of the city might be a function of the crime level at one or more other areas. Using reported Index offenses in Washington, D.C., Budnick [A.2-16] showed the existence of such crime-correlated areas. However, the degree of correlation was not sufficiently high for prediction or "inference" purposes. Budnick also studied displacement effects of a police patrol experiment in Washington, D.C. He analyzed the spatial displacement of target crimes for 23 adjacent areas and concluded that there was displacement of crime into only three of these areas. Additionally, he analyzed temporal displacement using the crime-correlated area model and found no displacement effects. In conclusion, Budnick points out that his model may be potentially useful in evaluating the impact of street lighting on crime. He postulates that if areas can be identified which are crime correlated, and if some of these areas subsequently have street lighting improvements, then others can be used as control and displacement sites. It remains to be seen whether this analysis can be of practical application in designing street lighting evaluations.

Measures Framework

The measures framework component of the research design is discussed separately in Section 5.1.

Measurement Methods

Most of the requirements for measurement methods are incorporated implicitly in Exhibits 5.2, 5.3 and 5.4, but two requirements are given special emphasis here. First, *sampling* considerations apply when a population's attitudes or behavior are measured, and *measurement duration* is a consideration when taking into account the transient impact of street lighting and when compensating for regression artifacts.

Sampling

In all attitude and behavior impact measures, the test hypothesis specifies the target population (e.g., target area residents, night street users, police officers, etc.). This population must then be *sampled*, since it is not usually possible to interview or observe all members of the target population. Standard procedures for random sampling should, of course, be applied and documented, including documentation of non-responses and consideration of the minimum sample size required for meaningful analysis.

Another form of sampling may be desirable, that of random sampling of street lighting environments. This measurement method was used in the Norfolk attitude study to *compensate* for the non-random location of street lighting target areas, and is described more fully in Section 4.1.

Measurement Duration

Observed street lighting impacts may be *transient* for two reasons. First, an observed impact may be a spurious "Hawthorne effect;" that is, a bias introduced by the conduct of the experiment *itself*. Second, a true deterrent effect may in fact be only temporary.

One way to detect these transient effects is to extend the duration of the evaluation until the observed impacts have stabilized. Extending the duration of the evaluation may also be used to test for suspected regression artifacts by performing the experiment in successive periods *after* the street lighting project, when presumably, no new intervention is present. Care must be taken, of course, to verify that procedures used for determining the impact *expected* in the target area are not invalidated by the duration of the evaluation period, as other intervening effects are likely to occur in proportion to the duration of the evaluation period.

Analytic Techniques

Some problems in the existing analytic techniques are discussed in Section 3.1. The application of analytic techniques pertinent to street lighting projects is the subject matter of Section 5.3.

DATA COLLECTION

The data sources for the measures identified in Exhibits 5.2, 5.3 and 5.4 are well known. In general, they consist of records, surveys and observations. Examples of records include grant proposals, budget requests, progress reports, lamp and luminaire technical data, performance specifications, engineering drawings, bid specifications, maps, purchase orders, utility company billings, and Uniform Crime Reports.

Surveys may include interviews of citizens, police or offenders. Observations, which may play a greater role in street lighting evaluations than in other topic areas, include extensive participant interviews, light measurements and behavioral observations.

DATA PROCESSING

The procedures for *verifying* data are, of course, dependent on the nature of the data sources. Whatever procedures are employed should be documented by the evaluator. *Analysis* of data is discussed in greater detail in Section 5.3.

IMPACT ANALYSIS

The *results* of the evaluation are, of course, based on the degree to which the test hypotheses are confirmed or not. Since only a small portion of the information provided by the explanatory measures can be explicitly--and quantitatively--incorporated into the test hypothesis, an important part of the evaluation is the *interpretation* of the final results using *all* the information contained in the explanatory measures. In effect, rival hypotheses must be set up to identify the possible links between various bias factors and the observed impacts, and the explanatory measures must be examined for consistency with the test hypothesis and the rival hypotheses. Perhaps one of the rival hypotheses could prevail, or at least, be consistent with the observed results. Taking such a risk is, of course, necessary for an objective evaluation; avoiding it can only limit the evaluation's validity and usefulness.

5.3 ANALYTIC TECHNIQUES

All of the evaluations of street lighting and crime reviewed to date are seen in Section 4.1 to employ one of three basic analytic techniques: before/after analysis, regression analysis and time series analysis. In this section an overview is presented of these same analytic techniques, emphasizing their application to street lighting projects from a somewhat more general but critical perspective.

Despite their differences, the three analytic techniques all permit a quantitative assessment of whether observed impacts are statistically significant (i.e., whether they can be attributed to street lighting as opposed to random fluctuations or some more general trends in the impact measures).

It is important to identify the scope of the material presented in this section. First, since the principles and assumptions underlying each technique are well known, they are not repeated here. Second, a general description of the application of these techniques is given, along with any special requirements the techniques may impose on the other elements of the research design that is described in Section 5.1. Finally, some *problems* which arise when applying the techniques to street lighting projects are noted.

BEFORE/AFTER ANALYSIS

Before/after analyses are conceptually simpler and relatively more straightforward to apply than the other two techniques. This does not mean, however, that they are immune to misuses, as seen in Section 4.2.

Three types of before/after analysis are described in this subsection: simple (i.e., before/after) comparisons; controlled (i.e., before/after, target/control area) comparisons; and controlled comparisons with ratio method. The first two are well known and have been used in the Evaluation Sample studies. The third approach, based on a *ratio method* for estimating expected values of impact measures, has not been previously reported, nor has it been extensively tested. It is described in somewhat more detail than the other before/after techniques in order to make possible its *further* development in future street lighting evaluations.

Simple Comparisons

A simple before/after test is obviously crude and yet it is a logical starting point for analysis. There is no point rushing to complicated techniques before even inquiring whether a significant change has taken place. The non-use of control areas may be justified when crime patterns in the target area have been shown to be relatively stable. This stability should be explicitly examined by testing data from several years prior to the street lighting project for seasonal variations, crime trends and random fluctuations. As noted in Sections 4.2 and 5.2, it is also important to avoid implicitly combining irrelevant assumptions with the street lighting test hypotheses.

If data are sufficiently detailed, it is also possible to define certain comparisons *within* the target area alone (e.g., night/day or street/non-street, or combinations of these) which further isolate the effect of street lighting. These are best seen as a special case of the ratio method, which is discussed below.

When crime levels in the target area have not been stable, the usefulness of simple before/after comparisons has been limited, since the chi-square test will have difficulty distinguishing the post-relighting variation from that which occurred before. Control areas are then required to sharpen the focus of the technique onto the street lighting intervention.

Controlled Comparisons

The classic example of a controlled comparison is a chi-square test of a table of before/after, target/control area impact measures. As noted in Section 5.2, the reasonableness of the control area should be tested, for example, by applying the above four-way comparison to data from the period *before* relighting. The precautions made above concerning the test hypotheses apply here, as well.

Controlled comparisons may also be used for a limited analysis of displacement effects, by testing the elements of a compound hypothesis. The components of the compound hypothesis can be identified as: A) a significant crime reduction has taken place in the target area; B) a significant crime increase has taken place in the displacement area; and C) the magnitudes of the changes are consistent with the overall displacement hypothesis. Separate tests should be performed on A and B with whatever control areas are appropriate for each. Identification of the magnitude of the changes may be difficult if they take place in the presence of large fluctuations or trends. Temporal displacement may be similarly analyzed by comparing before/after and night/day crime in the target and control areas. However, there is no way to assure that this approach will include all possible displacement areas or forms of displacement. Hence, a negative result does not imply the absence of displacement. This limitation is inherent in the present lack of understanding as to the analysis of crime displacement.

The main difficulty with the application of controlled before/after comparisons is that a *systematic* approach is required for a) avoiding implausible stability assumptions and b) defining an orderly set of comparisons which focuses on the effects of street lighting and exhausts the possibilities contained within the data. The ratio method, discussed next, promises to contribute to the resolution of these difficulties.

Controlled Comparisons with Ratio Method

The ratio method begins with the observation that, prior to the street lighting intervention, crime *levels* are erratic, but certain ratios are not. For example, within the relit area, the ratio of night street robbery to night non-street robbery may be relatively more constant than either of the levels themselves. Similarly the ratio of night street robbery in the target area to that in a control area may be stable, even if their absolute levels are dissimilar.

Assuming the reasonableness of this assumption, the ratio method postulates that ratios observed to be stable prior to relighting would *remain* so if the street lighting project did not take place.

The pre-relighting ratios are thus used as the basis for predicting the expected distribution of post-street lighting ratios. The remaining discussion addresses the confirmation of the ratios' stability; and the use of particular ratios in chi-square tests of street lighting impact. A somewhat detailed discussion is given, since the approach is novel and not described elsewhere.

Confirmation of Stability

Examples of the reasonableness of the ratio method's underlying assumption are not difficult to find. For example, using the Denver data, quarterly ratios of street lighting target area to city-wide night violent crimes in 1973 and 1974 were, respectively, .207, .205, .186, .200, .197, .186, .190 and .191. Even with such a crude comparison, the quarterly ratios are all seen to drop to below .175 in 1975, the first year after relighting.

In practice, a more systematic approach should be taken, as the following example illustrates. It is assumed that there are three districts, one totally relit, one partially relit and the third not relit, which are labelled 1, 2 and 3, respectively.* Using night street robbery as the target crime, three ratios are defined as follows:

*In practice, the three labels might equally well denote a target, control and displacement area.

$$SI_i = NSR_i / (NSR_i + NIR_i)$$

$$ND_i = NSR_i / (NSR_i + DSR_i)$$

$$R_{ij} = NSR_i / (NSR_i + NSR_j)$$

where NSR_i = number of night street robberies in area i,

NIR_i = number of night non-street or robberies in area i, and

DSR_i = number of day street robberies in area i.

One first estimates whether the ratios above have been stable before the relighting. Suppose, for instance, that in area 1, the following data prevail for three six-month periods *prior* to relighting:*

	Period 1	Period 2	Period 3	Total
NSR_1	40	60	55	155
NIR_1	20	31	25	76
Total	60	91	80	231

It is seen that SI_1 is quite constant over the three periods (i.e., .667, .659 and .688, respectively), with an average value equal to .671 (i.e., 155/231). A straightforward chi-square test with two degrees of freedom shows the variations during the three pre-relighting periods to be random fluctuations. Thus, it seems reasonable to choose as a test hypothesis the statement that "each

*It should be noted that *fictitious* data are employed in this section, for illustrative purposes only.

night robbery in period 4 (i.e., after the lights are installed) has a probability of .671 of occurring on the street." If the ratio SI_1 were measured to be substantially *lower* in period 4, the result would support the deterrent effect of the street lighting. Testing one ratio does not, however, make it possible to distinguish the various possible forms of deterrence (e.g., displacement to indoors, displacement to other areas or an absolute reduction).

Other ratios (e.g., ND_i and R_{ij}) can be similarly examined. It may be speculated that even if the ratios are not constant, it could be possible to find a causal model for the observed change. Mere extrapolation of a systematic trend, however, should not be done since a causal explanation, if found, could conceivably predict a change in the trend. In any case, if a particular ratio is not stable or predictable, it should be excluded from the analysis. Obviously, if no constant ratios can be identified, then the ratio method should not be used.* Based upon a preliminary application to available street lighting and crime data, the ratio method promises to be an effective analytical tool.

Testing of Ratios

The actual test of the impact of street lighting is governed by the ratios selected. The use of two of the ratios defined above (i.e., ND_1 and R_{13}) is illustrated by the example below.

Suppose that review of the data has shown that the ratios for the pre-relighting period are $ND_1 = 1/2$ and $R_{13} = 1/3$. If the relighting has no major effect, one would expect both of these ratios

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* Also, if time of day is unknown for a large fraction of reported crimes (e.g., as with business burglaries), then those crimes should be excluded from any analysis, including the ratio method.

to continue to prevail, except for fluctuations. On the other hand, if the brighter lights had a deterrent effect, then both ratios are expected to decline (except for fluctuations). Finally, if the lights actually *increased* reported crime, both ratios would probably go up. However, looking only at the *direction* of the difference between the actual and the expected post-relighting ratios is far too crude: there is a good possibility that chance alone would move both ratios in one direction, since their common numerator causes random influences in the two ratios to be positively correlated.

A suitable test hypothesis is the statement that "the actual values ND_1 and R_{13} for the post-relighting period differ from their predicted values only because of randomness." Based on this hypothesis, the value of ND_1 (i.e., 1/2) implies that for every ℓ night street robberies in area 1 after the relighting, there should also be ℓ day street robberies in the same area. The value of R_{13} (i.e., 1/3) implies that there should be 2ℓ night street robberies in the non-relit area for every ℓ in the relit. No prediction is made for day street robberies in the non-relit area.

Thus, if the relighting is *not* effective, the fractions of all street robberies in the three settings (i.e., NSR_1, DSR_1 and NSR_3) should be .25, .25 and .50, respectively. A straightforward chi-square test comparing the observed and expected street robbery data may then be performed.

It is noted that the above example, although deliberately simple for ease of exposition, includes in a natural and almost unobtrusive way the merger of comparisons *within* the relit area and *between* the relit area and another area. The chi-square test in effect "weights" the evidence from comparisons *within* and *between* different areas. In contrast, Kansas City, the only Evaluation Sample study making both types of comparison, had no procedure for combining such findings, or deciding what to do if different comparisons gave results in opposite directions. The ratio method also weighs the *strength* of individual clues, and not merely their *directions* in a statistically defensible way.

It should be noted that the particular ratios used in this example are not the only ones possible. The approach could be generalized to include other ratios expressing stable patterns which are expected to be altered by street lighting. And, of course, the example only includes one crime type (i.e., robbery).

The intention here is only to illustrate the possible use of the method by a relatively simple example. It is recommended that the ratio method be further developed and refined by application to readily available data from a past or ongoing street lighting evaluation effort.

REGRESSION ANALYSIS

Multiple regression analysis is, of course, a well-known technique which has been widely applied in criminal justice research. Its potential significance to street lighting evaluations lies in its ability to deal with a large number of explanatory variables. It has, in fact, been used successfully in studies of street lighting and traffic accidents [A.2-66]. Regression analysis deals explicitly with a problem handled only indirectly by the use of control areas in other techniques. Further, it permits the use of continuous measures of light rather than the relit/non-relit dichotomy of the other techniques.

Schematically, the typical regression analysis assumes that the impact measure, I, can be modelled as:

$$I = a + bL + cS + dA + e,$$

where L stands for a light measure, S is a socio-economic measure, A is an attitude measure, e is a random fluctuation with some standard deviation σ, and a, b, c, d and σ are constants estimated from analysis of the data. In practice, of course, the number of measures may be greater or fewer. For example, Norfolk used several light measures, including vertical and horizontal illumination, as well as uniformity. The measures also need not be continuous--for example, L could be 0 or 1 for non-relit and relit blocks, respectively. Finally, the measures need not be absolute values--I and/or L may represent *changes* in the impact or light measures from before the street lighting project to after.

The problem with regression analysis is that, having taken on many difficult issues, it does not necessarily resolve them. Two problems are noted. First, defining a *complete* set of independent variables is always problematic, as is the danger of "washing out" the variance in the data with too many variables. The method itself offers no guidance to the evaluator.

Second, even with all key variables present regression results can be highly inaccurate, because of the assumption of a linear relationship between measures. For example, as postulated in Section 6, fear may not be a linear function of light. However, it might be approximated by a *series* of linear relationships, each applied to a given range of the pertinent light measure(s). At the very least, the reasonableness of the assumed functional form should be checked by examining its behavior in limiting cases. For example, a regression equation with coefficients estimated from data on one set of streets could be tested for its accuracy in predicting crime levels on others. This is in theory a standard procedure, but its absence in practice is noteworthy.

In conclusion, regression analysis has much to recommend it, but it remains virtually untested in the topic area of street lighting and crime. Wherever it is applied, its results and assumptions should be subjected to strenuous testing.

TIME SERIES ANALYSIS

One problem in evaluating law enforcement programs is that the impacts occur in a time series. Thus, the before and after distributions of data are *dependent*. Also, since the underlying process is often *not* stationary (due to the many external factors that are working on the system), the before and after distributions probably do not have the same mean and variance. Hence, confidence intervals and significance levels obtained using classical statistics have little credence, since not all the necessary assumptions are valid.

In time series analysis, these problems are addressed by assuming that fluctuating events from successive periods are *correlated.* Such an assumption is especially plausible if publicity about certain incidents tends to stimulate others and thus creates crime waves--as seems to happen for suicide and hijacking. A simple time-series model might go as follows: before the relighting the level X(t) of, say, night street robbery in the period t is given by:

$$X(t) = T + e(t)$$

while after the relighting, X(t) becomes:

$$X(t) = T + \delta + e(t)$$

where T and δ are constants and e(t) is a normally-distributed random fluctuation term with zero mean and standard deviation σ. The coefficient of correlation of X(t) and X(t+1) is ρ. T, δ, ρ, σ are estimated from data analysis, and the uncertainties in the estimates are specified. Whether δ differs from zero in a statistically significant way becomes the focus of attention; this is determined by examining whether the 95 percent confidence interval for δ includes zero.

In practice, however, a significant amount of *systematic* variation in X(t) may be due to influences other than the street lighting, in which case the assumption that e(t) is purely random is not valid. A recently reported method by Box and Tiao [A.2-11] for addressing this difficulty entails modelling both the noise function e(t) and the impact of the intervention in such a way that the discernment of the effects of the intervention is enhanced. This "intervention analysis" prescribes an iterative procedure for entertaining successive mathematical models until the best fit with the data is obtained.

To date, only one application of this method is known to have been made in street lighting; it was applied to monthly night business burglary data from the New Orleans evaluation [A.2-73]. A conventional analysis assuming a random noise function e(t) was performed first, indicating an apparent street lighting impact. However, further inspection revealed that the randomness assumption was not valid for e(t). The intervention analysis method was then applied, yielding a model with a more accurate fit to the data. Contrary to the first result, the impact attributable to street lighting was found to be negligible. The study concludes that errors can arise if the serial dependence of successive observations is ignored. It should be noted that this method requires a large number of data points. For example, in the New Orleans intervention analysis, 50 "before" and 29 "after" values were used.

Because of the underlying theoretical considerations, and in view of the findings on the New Orleans data, continued efforts to apply the intervention analysis method to other data on street lighting and crime are warranted, and, in fact, have been supported by NILECJ.*

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6 CONCLUSIONS

The purpose of this section is to draw conclusions from the material presented in Sections 1 through 5. The present state of knowledge is discussed in Section 6.1; gaps in knowledge and related recommendations are summarized in Section 6.2; and future research and evaluation activities are identified in Section 6.3.

6.1 STATE OF KNOWLEDGE

Is street lighting an effective approach in the reduction and deterrence of crime? The answer is inconclusive. The paucity of reliable and uniform data and the inadequacy of available evaluation studies preclude a definitive statement regarding the relationship between street lighting and crime. Although there is *no* statistically significant evidence that street lighting impacts the level of crime, especially if crime displacement is taken into account, there is a *strong* indication that increased lighting--perhaps lighting uniformity--decreases the fear of crime.

A related question is: Could a *definitive* statement have been made regarding street lighting and crime, even if reliable and uniform data were available and the evaluation studies were adequate? The answer is no. The street lighting and evaluation issues considered in Sections 2 and 3.1, respectively, would have rendered any such statement questionable and invalid. In particular, on a microscopic level, there is a lack of understanding regarding which light measure, or combination of measures, is correlated with an individual's perception of personal security; and, on a macroscopic level, there is a problem with existing analytic techniques, especially in regard to an evaluation of synergistic effects. Research activities to overcome these problems are identified in Section 6.3.

A final question is: For the purpose of guiding immediate policy decisions, what can be assumed about street lighting and crime? The answer is that, although it does not seem to impact the level of crime and may in fact displace crime, street lighting can be *assumed* to affect the fear of crime. Despite the fact that this assumption is based on very limited statistical evidence, one's intuitive sense that street lighting makes an environment less alien provides an overwhelming argument in support of the assumption. Certainly, in this day and age, a completely darkened street would make one quite fearful and concerned. On the other hand, raising the illumination level to, say, daylight levels, would not eliminate one's fear of being victimized, since crimes do occur during the day.* Actually, fear is probably not a linear function of light (i.e., whatever measure or combination of measures characterize light), but is a stepwise function of light; that is, the level of fear remains relatively constant between certain ranges of light and changes significantly at other ranges.

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* Continuing in this line of thought, one might postulate that the maximum impact of street lighting on crime in a given target area is bounded by the number of crimes that occur in the area during the day, since the brightest street lighting system is that provided by daylight. Care must be taken in this postulation, however, since the land use characteristics during the day are usually different from those at night.

Given the above assumption, it is recommended that the LEAA *continue* to fund street lighting projects for the purpose of deterring crime, recognizing that the objectives of street lighting are not only safety and security, but also community character and vitality, as well as traffic orientation and identification. In fact, the funding of street lighting projects should be a joint inter-agency effort so that the *range* of objectives is taken into consideration in the development of the project.

6.2 GAPS AND RECOMMENDATIONS

The gaps or problems in the state of knowledge have been discussed in terms of the street lighting and evaluation issues in Sections 2 and 3.1, respectively. Exhibit 6.1 summarizes the various issues, gaps and recommendations.

A quick review of Exhibit 6.1 reveals that some gaps are beyond the scope of a study on street lighting and crime. For example, the weaknesses in the UCR crime measures must be addressed by the entire criminal justice community. On the other hand, the majority of the remaining gaps can be overcome by the conduct of three activities. First, research is required to define pertinent light measures. Second, research is required to identify more relevant analytic techniques. Third, an exemplary street lighting evaluation is required to serve as a *model* evaluation. Unfortunately, none of the available evaluations can serve as a model. All three activities are detailed in the next section.

Exhibit 6.1

State of Knowledge: Issues, Gaps and Recommendations

Issues	Gaps	Recommendations
Project		
• Project Responsibility Is Diffuse	• Project Coordination Is Lacking • Data Acquisition Is Difficult	• While the very nature of a crime-related street lighting project requires the participation of a number of different city agencies, it is necessary that a temporary inter-agency committee be established for the lifetime of the project (i.e., from planning through evaluation). The committee should be responsible for coordination among the agencies and with outside contractors, as well as for the collection and analysis of pertinent data.
• Project Funding Sources Are Many, Each With A Narrowly Focussed Mandate And A Desire For Quick Results, Usually Without Benefit Of Evaluation	• Project Objectives Are Unrealistically Narrow In Focus • Possibility Of Regression Artifacts In Evaluation • Evaluation Efforts Are Brief And Inadequate	• Inasmuch as street lighting serves a wide range of objectives, the above recommended inter-agency committee should *simultaneously* seek funds from different sources and develop street lighting projects that are realistically responsive to the range of objectives and are accordingly evaluated for a reasonable length of time. Furthermore, the funding sources should also support evaluation-related activities in an explicit manner.
System		
• System Designs Are Lacking In Pedestrian-Oriented Emphasis And Constrained By Industry	• Existing Street Lighting Standards Are Lacking • Heavy Reliance On Industry	• If it can be *assumed* that street lighting affects crime, then pedestrian-oriented street lighting standards should be developed, and they should be *integrated* with roadway-oriented standards. Furthermore, since the public is the ultimate consumer of street lighting products, the federal government should take a more *active* role in the research and development of efficient and effective street lighting systems.
• System Measurements Are Minimal And Lacking	• Light Measurements Are Minimal • Cost Measurements Are Lacking	• More detailed and complete descriptions of performance specifications, cost breakdowns, and system characteristics are required. Pertinent light and cost measurements can be derived from these descriptions with the use of computer-based models (which still require further development, testing and calibration).
Related		
• Prevailing Energy Shortage And Conspicuousness Of Street Lights Have Made Street Lighting A Focus For Energy Conservation	• Opportunity For "Natural Experimentation" • Need For A Total Systems Approach	• Future street lighting illumination reductions due to energy conservation measures should (a) be monitored for possible "natural experiments", and (b) be guided by a total systems approach which would result in street lighting systems that are at once energy- and cost-efficient.
• The Law Is Becoming Increasingly Involved In Street Lighting Issues	• Building Security Ordinances • Possible Civil Liability	• Evaluations of street lighting and crime must be sensitive to local building security ordinances and civil liability suits (involving street lighting), and they must be careful about their conclusions, inasmuch as these conclusions may be used as arguments in court.
• Street Lighting Is Part Of A Larger Environment	• Need To Assess Environmental Impact • Need To Assess Concurrent Programs • Need To Assess Synergistic Effects	• In order to minimize any complications in implementing a street lighting project, an environmental impact analysis should be made. Furthermore, from an evaluation viewpoint, it is necessary to identify any concurrent programs or resultant synergistic effects that could impact the evaluation results.

Exhibit 6.1
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Issues	Gaps	Recommendations
Evaluation		
• Existing Evaluation Measures Are Inadequate	• Light Measures Are Inadequate • Attitude Measures Are Inadequate • Behavior Measures Are Inadequate • Crime Measures Are Inadequate	• Measures characterizing light, attitude (including fear of crime), behavior (including crime displacement) and crime are all inadequately defined, so that the evaluations, including street lighting evaluations, which are based on one or more of these measures, can be *expected* to be somewhat inadequate. These measures require better definition, testing and refinement.
• Existing Analytic Techniques Are Inadequate	• Existing Analytic Techniques Are Inadequate And Require Continued Research	• Various analytic techniques--including regression analysis, time series analysis, and before/after analysis--have been applied to "discern" the impact of a particular intervention; there are weaknesses in each technique. Discerning a synergistic effect is an even more complex issue. Although on-going CPTED evaluations should shed light on this issue, it is recommended that a research activity be undertaken to identify and test analytic techniques which can be effectively used in street lighting evaluations.
• There Are Several Possible Methodological Problems In Actual Evaluations	• Research Design Is Lacking • Explanatory Measures Are Lacking • Impact Measures Are Lacking • Analytic Techniques Are Misused	• In comparing the anticipated methodological problems with those actually observed in the various evaluation studies, it is noted that the observed problems include more than those anticipated--a reflection of the general naivete about how to design and conduct an evaluation. A *model* single project evaluation is recommended.
• Evaluations Can Be Costly	• Evaluations Can Be Costly, But May Be Cost-Effective	• A high cost evaluation is justified if it is a pioneering effort, while an evaluation modelled after another can be undertaken at minimal cost. It is recommended that the cost-effectiveness of each evaluation be considered on its own merits.
• Project Data Are Not Uniform	• Project Data Are Not Uniform, Thus Foreclosing Opportunity To Conduct A Phase I Or Multi-Project Evaluation At This Time	• The nature of project responsibility and the funding requirements make it difficult to acquire data that are consistent and uniform. A *model* evaluation would allow projects to collect and maintain comparable data.

6.3 FUTURE ACTIVITIES

Two research activities and one evaluation activity are recommended in this section. All three activities deserve immediate attention, and should be carried on concurrently, in coordination with each other. The two research activities attempt to *understand* the relationship between light and crime on a microscopic and a macroscopic level, respectively, while the evaluation activity would *assure* the uniformity and comparability of future street lighting evaluations.

RESEARCH ACTIVITY -- MICROSCOPIC LEVEL

Recent and ongoing studies in traffic safety [A.2-8, A.2-36, A.2-66] can guide the identification of a research agenda for a study of light and personal security. As discussed in Appendix B, these traffic studies have been able to develop and test a visibility index which (a) corresponds well to an intuitive notion of the factors determining visibility; (b) can be reliably derived from a knowledge of the characteristics of the environment (i.e., street lighting system and roadway surface); and (c) can be correlated with the actual behavior of motorists performing tasks relevant to traffic safety.

In developing an equivalent visibility measure for personal security, a possible research approach might require the following steps. First, identify a set of security-related visual tasks. A pertinent visual task might be defined as the detection, recognition or identification of a given visual target (e.g., facial feature, human silhouette, etc.) at a specified distance (e.g., at a "safe" distance, so that flight could be a feasible option) and in a given environmental setting. Second, measure the ability of a representative sample population to perform the visual tasks under a variety of lighting conditions. Third, define a set of target visibility measures--which hopefully would be based on existing light measures--that could be correlated with the ability to perform the visual tasks. Fourth, select the visibility measure(s), if any, that best correlate with the ability to perform the visual tasks and verify their predictability from a knowledge of the characteristics of the street lighting and contiguous environment. Fifth, test the visibility measure(s) by performing a correlation analysis with actual crime and fear data.

The conduct of this research activity would not only contribute to the evaluation of street lighting projects, but also provide the necessary information for the development of pertinent, pedestrian-oriented lighting standards. Consequently, the design of all future street lighting systems would benefit from this activity.

Finally, it is estimated that the activity would require five professional person-years of effort, supported with appropriate instrumentation and testing facilities. The activity could be carried out over a two-year period.

RESEARCH ACTIVITY -- MACROSCOPIC LEVEL

On a macroscopic level, the impact of street lighting on crime (and fear) can be affected by other variables; some of which are intervening and must be controlled for in any evaluative analysis, while others (e.g., special police patrol, neighborhood block watch program, Crime Prevention Through Environmental Design--CPTED--program, etc.) are supportive and must be evaluated for their synergistic effects. New analytic techniques, or hitherto unidentified use of existing techniques, are required to evaluate these synergistic effects.

It is recommended that readily available data from a past or ongoing street lighting evaluation be used to test any pertinent analytic technique that is developed. Actually, Section 5.3 identifies two techniques--the Box and Tiao "intervention analysis" [A.2-11] and the proposed "ratio method"--which deserve to be tested. The testing of these two techniques would only require one professional person-year and some data processing support. The development and testing of other analytic techniques would, of course, require a higher level of effort.

EVALUATION ACTIVITY

A somewhat better understanding of street lighting and crime can, of course, be had if a *major* street lighting project is developed and implemented, together with an extensive and expensive evaluation program. Unfortunately, as stated in Section 6.1, the results of such an elaborate effort *at this time*--without the benefit of the two aforementioned research activities--would still be questionable. Therefore, it is recommended that a major (i.e., NEP Phase II) street lighting evaluation effort not be undertaken now but that single project evaluations be conducted on a *systematic* and *uniform* basis, so that a *formal* NEP Phase I evaluation could be profitably undertaken at a later point in time--perhaps three to five years from now.

However, in order to *insure* the existence of a systematic and uniform set of single project evaluations, it is necessary to develop a *model* evaluation that could be used as a guide and reference. Therefore, it is recommended that the single project evaluation design, which is contained in Section 5, be applied to either a past or ongoing street lighting project; this would probably require about one to two professional person-years of effort. Such an application would also help to refine the design, which could be used in all subsequent evaluations.

APPENDIX A

REFERENCES AND CONTACTS

To facilitate the identification of references dealing exclusively or primarily with individual cities, counties or states, the list of references is presented here in two separate exhibits. Exhibit A.1 contains only those references dealing with specific governmental jurisdictions, and is organized alphabetically by jurisdiction. Exhibit A.2 contains all other references, including several which refer to more than one jurisdiction--these are cross-indexed, where appropriate, in Exhibit A.1. Finally, Exhibit A.3 lists individuals who have been contacted either by telephone, in person, or through written correspondence during the course of this evaluation study, and who have furnished data or other information concerning street lighting and crime.

Both Exhibits A.1 and A.2 identify the specific contribution of each reference document to the study. The five areas to which each document can contribute are: background, elements, interventions, environment, and evaluation. *Background* includes materials pertaining to the history of street lighting practices and goals, and to the development of evaluation methods in the area of crime prevention. *Elements* include all of the components and activities encompassed by a street lighting system: resource allocation, design, hardware, installation and maintenance practices; supporting activities or activities supported by street lighting (e.g., police patrol, street reconstruction, tree trimming, etc.); and system outputs and impacts (e.g., lighting, crime and fear levels). *Interventions* include reports on measured crime-related consequences of street lighting activity and hypotheses which attempt to explain how these consequences arise. *Environmental* contributions include documents dealing with important issues which, although only indirectly related to the crime prevention effects of street lighting, are relevant to questions of resource allocation, design, environmental and legal constraints. Finally, *Evaluation* contributions are those that bear directly on the design and conduct of alternative street lighting evaluations, both existing and potential.

Documents reviewed and found to have no relevance to street lighting and crime are not included in Exhibits A.1 and A.2. Throughout the text of this report, references are keyed to the two exhibits and the sequence number within each exhibit. For example, reference [A.2-14] refers to Box, Paul, "Public Lighting Needs," Illuminating Engineering, September, 1966. It should also be noted that a number of references which appeared in the "Issues in Street Lighting and Crime" report [A.2-112] have been omitted from Exhibits A.1 and A.2. The omissions consist largely of documents which were written for the popular media (e.g., newspapers and magazines) and which were either summary documents of other published reports or journalistic accounts that could not be verified.

Exhibit A.1

Street Lighting References by Jurisdiction

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
			CONTRIBUTION				
Asheville, NC[1]	1.	Asheville, North Carolina Police Department, "Crime in Downtown Asheville within Study Area," Copy obtained from National Crime Prevention Institute, (undated).			X		
Atlanta, GA	2.	City of Atlanta, Georgia, Traffic Engineering Department, "Street Lighting Pilot Project," Application for Grant 72-09-07-17, August 31, 1972.	X	X	X		
Atlanta, GA	3.	Atlanta Impact Program, "Street Lighting Pilot Project, Grant No. 72-09-07-17, Quarterly (April 17, 1974) and Semi-Annual (November 8, 1974) Evaluation Reports." Atlanta Regional Commission, Atlanta, Georgia.			X		
Atlanta, GA	4.	"Street Lighting Project Funded," <u>The Atlanta Journal</u>, March 9, 1973.			X		
Baltimore, MD	5.	City of Baltimore, Maryland, Mayor's Coordinating Council on Criminal Justice," Sodium Vapor Street Lighting - Report on Resident Survey," August 1975.			X		X
Baltimore, MD	6.	Mastromatteo, Dominic, Baltimore, Maryland, Police Department, May 25, 1970 letter to F. Pierce Linaweaver, Director of Public Works, Baltimore, Maryland.			X		
Chattanooga, TN	7.	General Electric Co., Nela Park, Cleveland, Ohio, "1,000 Watt Lucalox Relighting in Downtown Chattanooga Gives Four Times the Light Without Adding to Energy Needs," Press Release No. 134-75, October 29, 1975.		X		X	
Chicago, IL	8.	Chicago Association of Commerce and Industry, Minutes of the June 22, 1972 Crime Prevention Committee Meeting.		X	X		
Chicago, IL	9.	Chicago Police Department, James M. Rochford, Superintendent, February 13, 1976 letter to Francis M. Degman, Acting Commissioner, Bureau of Streets and Sanitation, crime summary enclosed.			X		X

[1] See also Reference A.2-45.

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
			CONTRIBUTION				
Chicago, IL	10.	General Electric Company, Nela Park, Cleveland, Ohio, "Lucalox Relighting of Chicago Streets Doubles Illumination, Cuts Energy Usage," April 11, 1975, Press Release No. 42-75.		X		X	
Cincinnati, OH	11.	Malt, Harold Lewis, and Associates, "Operation STREETSCAPE--A Demonstration Furnishing the City Street," prepared for the Department of Urban Development, Cincinnati, Ohio.		X		X	
Cleveland, OH	12.	City of Cleveland, Department of Public Utilities, "Impact Street-lighting Project Evaluation Report -- September 1973 Through November 1974."		X			
Cleveland, OH	13.	City of Cleveland, "Impact Street-lighting," LEAA Grant Application 73DF05S015, 6/1/73-6/30/74.		X			
Danville, IL	14.	Pitt, Paul J., East Central Illinois Criminal Justice Commission, letter to Gerald Gersey, Illinois Law Enforcement Commission, March 30, 1972.			X		X
Denver, CO	15.	City and County of Denver, Colorado, Streetlighting Project, Application for Grant 75-DF-08-0002 (H).		X	X		X

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
			CONTRIBUTION				
Denver, CO	16.	Denver Anti-Crime Council, "Final Report -- Street Lighting Project," Unpublished Draft, June 1977.			X	X	X
Detroit, MI	17.	Head, John F., "New Street Lights May Harm Trees," Detroit Free Press, October 1, 1973, p. 3A.				X	
Detroit, MI[1]	18.	Luedtke, Gerald and Associates, "Crime and the Physical City: Neighborhood Design Techniques for Crime Reduction," a Pilot Study prepared for the National Institute of Law Enforcement and Criminal Justice, Michigan, June 1970.			X		X
Garland, TX	19.	City of Garland, Texas, Crime Prevention Environmentalist, Grant Application No. 5-11-03018, August 22, 1975.			X		
Greendale, WI	20.	"The People's Choice in Roadway Lighting," Illuminating Engineering, March 1970, p. 121.		X			

[1]See also Reference A.2-82.

Exhibit A.1

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JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
Harrisburg, PA	21.	Harrisburg Police Department, "Final Evaluation Report of the 'High Intensity Street Lighting Program' Subgrant No. SC-74-C-B1-6-239-S," Planning and Research Section, Staff and Technical Services Division, August 1976.					X
Indianapolis, IN	22.	"Blueprint for Good Lighting," Street and Highway Lighting, (date unknown).		X			
Indianapolis, IN	23.	"Clubwomen Turn Lights on Crime," Atlanta Journal and Constitution, October 22, 1972, p. 15-H.		X	X		
Indianapolis, IN	24.	Dunn, Jack, "Crime? Blight? We Fix It," Outdoor Lighting Digest, January 1969, pp. 3-4.			X		
Indianapolis, IN	25.	"Planned Light Prevents Crime and Reduces Accidents," The American City," March 1963, pp. 125-126.			X		
Jacksonville, FL	26.	Malt, Harold Lewis et al., "Tactical Analysis of Street Crime," H.L. Malt Associates, Washington, D.C., January 1973.			X	X	
Jeffersontown, KY	27.	Kellem, Carl, Harmansky, George, Landan, Elizabeth, and West, John Denis, "A Comprehensive Study of Streetlighting with an In-Depth Analysis of Plainview Subdivision, Jeffersontown, Kentucky," Institute of Community Development, University of Louisville, Louisville, Kentucky, April 23, 1976.	X	X	X	X	X

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
Kansas City, MO	28.	Kelling, George L., Pate, Tony, Dieckman, Duane, and Brown, Charles E., "The Kansas City Preventive Patrol Experiment: A Technical Report," prepared by the Police Foundation, October 1974.					X
Kansas City, MO	29.	Pate, Tony, Bowers, Robert A., and Parks, Ron, "Three Approaches to Criminal Apprehension in Kansas City: An Evaluation Report," prepared by the Midwest Research Institute and the Police Foundation, 1976.					X
Kansas City, MO	30.	Wright, R., Heilweil M., Pelletier, P., and Dickinson, K., "Impact of Streetlighting on Crime," prepared by the University of Michigan, Ann Arbor, for the National Institute of Law Enforcement and Criminal Justice, Grant No. 73-NI-99-0046-G, May 1974.	X	X	X	X	X
Kansas City, MO	31.	Wright, R., Thomas, D., Pelletier, P., and Dickinson, K., "Study to Determine the Impact of Streetlighting on Crime - Phase I Final Report," prepared by the University of Michigan, Ann Arbor, for the National Institute of Law Enforcement and Criminal Justice, 1972.			X		X

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JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	CONTRIBUTION: Background	Elements	Interventions	Environment	Evaluation
Kansas City, MO (continued)	32.	Wright, R., Thomas D., Pelletier, P., and Dickinson, K., Kansas City Public Works Department, "Study to Determine the Impact of Streetlighting on Crime - Phase II Final Report," prepared by the University of Michigan, Ann Arbor, for the National Institute of Law Enforcement and Criminal Justice, July 1973.		X	X		X
Lincoln, NB	33.	"Annual Report: September 1, 1975 to August 31, 1976," Lincoln Electric System, Lincoln, Nebraska.		X			
Lincoln, NB	34.	"Preliminary Official Statement: Electric System Revenue Bonds," City of Lincoln, Nebraska, March 5, 1976.		X			
Massachusetts	35.	Massachusetts Department of Community Affairs, Energy Conservation Project, "Energy Management in Municipal Street Lighting," March 1, 1977.				X	
Massachusetts	36.	Massachusetts Department of Public Works, "Highway Lighting and Electrical Energy Conservation - Vol. 1, General Warrants and Recommendations," February 1974.				X	
Miami, FL	37.	Clements, Sid, "Sodium Vapor Lighting Cuts Crime," Electrical South, April 1972, pp. 27-31.			X		

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JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	CONTRIBUTION: Background	Elements	Interventions	Environment	Evaluation
Miami, FL (continued)	38.	Francis, Edward, "Miami Relights: A Report on Street Lighting Programs and Procedures in the City of Miami," Department of Public Works, City Commission of Miami, Report No. 232, December 1973.		X	X	X	
Miami, FL	39.	Miami, Florida, Department of Public Works, "A Brief Update on 'Miami Relights'," July 1976.			X		
Miami Beach, FL	40.	City of Miami Beach, Florida, "Project for Illumination of High Crime Areas," application for LEAA Grant, March 16, 1973.	X	X	X	X	
Miami Beach, FL	41.	Harold Lewis Malt Associates, "Illumination of High Crime Areas," conducted for the City of Miami Beach, Florida, co-sponsored by the State of Florida Governor's Council for Criminal Justice, 1974.		X		X	
Milwaukee, WI	42.	Milwaukee, Wisconsin, Department of Intergovernmental Fiscal Liaison, "Final Report--Milwaukee High Intensity Street Lighting Project," July 15, 1974.			X		X
Milwaukee, WI	43.	Milwaukee, Wisconsin, Department of Intergovernmental Fiscal Liaison, "Final Report--Milwaukee High Intensity Street Lighting Project--Area #2," September 1, 1975.					X

Exhibit A.1

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JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
Milwaukee, WI (continued)	44.	Milwaukee, Wisconsin, Department of Intergovernmental Fiscal Liaison, "Preliminary Report--Milwaukee High Intensity Street Lighting Project," December 28, 1973.			X		X
Newark, NJ	45.	City of Newark, New Jersey, "Impact Street Lighting," application for Grant 72-DF-02-0100.	X	X	X		
Newark, NJ[1]	46.	Kupersmith, G., "Sample Impact Project Evaluation Components--National Impact Program Evaluation," prepared by MITRE Corporation for the National Institute of Law Enforcement and Criminal Justice, 1974.					X
Newark, NJ	47.	Newark High Impact Evaluation Staff, "Street Lighting Project Interim Evaluation Report," December 1975.			X		X
New Haven, CT	48.	South Central Criminal Justice Supervisory Board, New Haven, Connecticut, "Innovative Patrol Operations," 1976.					X

[1]See also Reference A.2-45.

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluations
New Orleans, LA	49.	New Orleans Mayor's Criminal Justice Coordinating Council, "Crime Reduction through Increased Illumination - A Preliminary Evaluation of the Impact of High Intensity Street Lighting," July 1, 1975.			X		X
New Orleans, LA	50.	Sternhell, Robert, "The Limits of Lighting: The New Orleans Experiment in Crime Reduction," Final Impact Evaluation Report, New Orleans Mayor's Criminal Justice Coordinating Council, April 15, 1977.			X		X
New Orleans, LA	51.	Sternhell, R. and Carroll, S., "Target Area Evaluation--A Six-Month Report on the Development of Target Area Projects and the Evaluation System," New Orleans Mayor's Criminal Justice Coordinating Council, 1974.	X	X		X	
New York	52.	Lurkis, Alexander, "Combatting Juvenile Deliquency with Light," <u>Illuminating Engineering</u>, October 1961, p. 606.		X	X		
New York	53.	Lurkis, Alexander, "More Lighting and Fewer Juvenile Problems," <u>The American City</u>, January 1962.		X	X		

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	CONTRIBUTION Background	Elements	Interventions	Environment	Evaluation
New York (continued)	54.	New York City Police Department, "Lighting as a Deterrent," obtained through Wilfred Horne, Deputy Commissioner for Press Relations, September 11, 1970.			X		
New York	55.	"New York City Requires Outdoor Lighting Around Multiple-Family Dwellings," (date and publication unknown), obtained from General Electric Company, Nela Park, Engineering Applications Department.				X	
New York	56.	"Vandal-Proof Lighting for New York City's Central Park," The American City, October 1966.		X			
Norfolk, VA	57.	Barr, Vilma, "Improving City Streets for Use at Night--The Norfolk Experiment," Lighting Design and Application, April 1976, p. 25.		X	X	X	X
Norfolk, VA	58.	"First Award--Gary Hack and William Lam Associates," Progressive Architecture, 1:75.		X	X	X	
Norfolk, VA	59.	Hack Gary, "Improving City Streets for Use at Night (The Norfolk Experiment)," prepared for the Norfolk Redevelopment and Housing Authority and William Lam Associates, June 1974.		X	X	X	X

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	CONTRIBUTION Background	Elements	Interventions	Environment	Evaluation
Norman, OK	60.	Speer, Ralph E., Jr., "Proposed Improvements to Street Lighting West of the (University of Oklahoma) Campus," memorandum to Richard N. Gray, Norman, Oklahoma City Manager, October 15, 1975.		X	X		
Plainfield, NJ	61.	"Plainfield Lights Up to Catch a Thief," New Jersey Municipalities, June 1973.			X		
Portland, OR	62.	City of Portland, Oregon, "Union Avenue Corridor Lighting and Night Crime Deterrence Program," application for Grant 75-DF-100103, March 20, 1975.	X	X	X		
Portland, OR	63.	Inskeep, Norman R. and Goff, Clinton, "A Preliminary Evaluation of the Portland Lighting Project," Oregon Law Enforcement Council, Salem, Oregon, August 1974.			X		X
Portland, OR	64.	Schneider, Anne L., "Crime and Victimization in Portland: Analysis of Trends, 1971-1974," Oregon Research Institute, Salem, Oregon, February 10, 1975.					X
Portland, OR	65.	Schneider, Anne L., "The 1974 Portland Victimization Survey: Report on Procedures," Oregon Research Institute, Salem, Oregon, January 8, 1975.					X

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JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
Portland, OR (continued)	66.	Schneider, Anne L. and Reiter, Paul, "Portland Lighting Project --Final Report--Citizen Perceptions of Streetlighting," Oregon Research Institute, August 1, 1975.					X
Richmond, VA	67.	PRC Public Management Services, Inc., "Richmond HIT Project--Final Evaluation Report for Phase I HIT Program," prepared for Virginia Division of Justice and Crime Prevention.			X		X
Richmond, VA	68.	Ryan, David D., "City Checks for Tree Damage," Richmond Times Dispatch, October 5, 1973.				X	
Salem, OR		See Reference A.2-45.					
Savannah, GA	69.	"Lighting Decreases Crime Rate," Municipal South, (date unknown).			X		
Savannah, GA	70.	Stuckey, W.S., "Street Lights Save Energy, Make Savannah a Safer Place to Live," Congressional Record, 94th Congress, 1st session, Vol. 121, No. 2, January 15, 1975.			X	X	
Smyrna, DE	71.	City of Smyrna, Delaware, Burglary Control Program, Grant Application No. 76-075.		X			

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
Tampa, FL	72.	"Tampa Relights 70 Square Blocks," Street and Highway Lighting, September 1971, pp. 7-9.		X	X		
Tucson, AZ	73.	City of Tucson, Arizona, "Dusk to Dawn Alley Lights," application for LEAA Grant No. 70-DF-090417.		X	X		
Tucson, AZ	74.	Garmine, Bernard L., "Light up for Safety," Congressional Record (Appendix), Extension of Remarks of Hon. Charles P. Farnsley, November 21, 1966, p. A-5574.			X		
Tucson, AZ	75.	Tucson Model Cities, "First Action Year--August 1, 1970-July 31, 1971 --Project Evaluation Report," Tucson Department of Human and Community Development, October 1971.					X
Washington, DC	76.	Basaran, Suat, "Crime Deterrent Lighting in Washington, D.C.," Traffic Planning and Street Lighting Division, Department of Transportation, Washington, D.C., 1973.			X		X
Washington, DC	77.	Basaran, Suat, "Crime Deterrent Roadway Lighting and Energy Use in the District of Columbia," Traffic Planning and Street Lighting Division, Department of Transportation, Washington, D.C., May 20, 1974.	X	X	X	X	

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	CONTRIBUTION: Background	Elements	Interventions	Environment	Evaluation
Washington, DC (continued)	78.	Colen, B.D., "D.C. Lights the Way in Fighting Crime," The Washington Post, February 7, 1971.			X		
Washington, DC	79.	"Cutting the Crime Rate: How the Nation's Capital Does It," U.S. News and World Report, April 10, 1972, pp. 24-25.			X		
Washington, DC	80.	Goodman, George and Schreider, F., "Light a Candle," Look Magazine, (date unknown).		X			
Washington, DC	81.	Hartley, John, "Lighting Reinforces D.C. Crime Fight," The American City, August 1974, p. 59.			X		
Washington, DC	82.	Hartley, John, "Nighttime Revival in the Nation's Capital," Nation's Cities, December 1970.		X	X		
Washington, DC	83.	"Improved Street Lighting in the District of Columbia," Congressional Record--Senate, October 9, 1970, p. S-17621.		X	X		
Washington, DC	84.	Landman, Amos, "Street Lighting Has Cut Crime," Journal of Commerce, May 18, 1972.			X		
Washington, DC	85.	Holland, William, "New D.C. Lights Cut Crime," The Evening Star, Washington, D.C., June 18, 1971.			X		

JURISDICTION		REFERENCE (Author, Title, Publisher and Date)	CONTRIBUTION: Background	Elements	Interventions	Environment	Evaluation
Washington, DC (continued)	86.	"New 'Globe Power' in Washington, D.C.," Street and Highway Lighting, Vol. 20, No. 4, 1970.		X	X		
Washington, DC	87.	"Washington, D.C.--Capital of Light," published by the District of Columbia, (date unknown).		X	X		
State of Washington	88.	"Evans Orders Street Lights On," The Seattle Times, February 7, 1974.		X		X	
Wichita Falls, TX	89.	Wichita Falls, Texas, Police Department, "Crime Analysis Data for Increased Street Lighting Program," 1976.					X

Exhibit A.2

Other Street Lighting References

REFERENCE (Author, Title, Publisher and Date)	Background	Elements	Interventions	Environment	Evaluation
1. Andreson, John W., "Street Trees are Safe With Sodium Lighting," American City, December, 1975.				X	
2. Angel, Shlomo, "Discouraging Crime Through City Planning," W.P. Number 75, Institute of Urban and Regional Development, University of California, Berkeley, February, 1968.			X		
3. Ashley, Myer, Smith, "City Signs and Lights, a Policy Study," prepared for the Boston Redevelopment Authority and the U.S. Department of Housing and Urban Development, January, 1971.		X	X	X	
4. Beardsley, Charles W., "Let There Be Light, But Just Enough," IEEE Spectrum, December, 1975, p. 28.		X		X	
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1.	Avant, Darwin	Criminal Justice Division, Office of the Governor, Austin, TX
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8.	Bennet, Beverly	U.S. Library of Congress, Washington, D.C.
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26. Crouch, C.L.	Illuminating Engineering Research Institute, New York, NY
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31. Dolan, Richard	Florida Bureau of Criminal Justice Planning and Assistance, Tallahassee, FL
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33. Edwards, Major Mike	Bureau of Police Services, Atlanta, GA
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37. Flynn, John E.	Architectural Engineering Department, Pennsylvania State University, State College, PA
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39. Fredericksen, Dale	Engineering Division, Norman, OK
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53. Hobson, Lieutenant R.D.	PACE Program, Police Department, Richmond, VA
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59. Johnson, P.J.	New York, NY
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67. Lipstein, Daniel	Mayor's Coordinating Council on Criminal Justice, Baltimore, MD
68. Lynn, Steven W.	Department of Human and Community Development, Tucson, AZ
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70. Malt, Harold Lewis	Harold Lewis Malt Associates, Inc., Washington, D.C.
71. Manshel, Bernice	State Law Enforcement Planning Agency, Trenton, NJ
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73. Markey, John	Public Service Gas and Electric Company, Passaic, NJ
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81. Mora, Francis	Public Works Department, Watertown, MA
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88. Pedrajo, Maria	Dade County Criminal Justice Planning Unit, Miami, FL
89. Pinkston, Charles	Facilities and Services Department, Asheville, NC
90. Pond, Chief	Police Department, Indianapolis, IN
91. Post, Margaret Moore	Indianapolis News, Indianapolis, IN
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94. Rayle, Officer Dennis	Research and Development Division, Police Department, Chicago, IL
95. Reed, Albert	Department of Transportation, Indianapolis, IN
96. Rhinehart, Sergeant Billy	Crime Prevention Unit, Police Department, Wichita Falls, TX
97. Rhule, Officer	Police Department, Salem, OR
98. Rice, David	Director, Planning and Program Development, Norfolk Redevelopment and Housing Authority, Norfolk, VA
99. Richard, LaVerne	Governor's Commission on Law Enforcement and the Administration of Justice, Cockeysville, MD
100. Richardson, James	Office of Justice Programs, Portland, OR
101. Roberts, James	Commissioner of Police and Fire, Chattanooga, TN
102. Rollins, Officer Larry	Police Department, Garland, TX
103. Rooks, James E., Jr.	Association of Trial Lawyers of America, Cambridge, MA
104. Ryan, Thomas	National Electrical Manufacturers Association, Washington, D.C.
105. Schiegg, Alan R.	Texas Crime Prevention Institute, Southwest Texas State University, San Marcos, TX
106. Schwab, Richard N.	Environmental Design and Control Division, Federal Highway Administration, U.S. Department of Transportation, Washington, D.C.

	Name	Affiliation
107.	Shapner, Martin	Tennessee Valley Authority, Chattanooga, TN
108.	Slavet, Joseph S.	Boston Urban Observatory, University of Massachusetts at Boston, Boston, MA
109.	Sloop, Craven M., Jr.	Duke Power Company, Charlotte, NC
110.	Smith, Marilyn	General Electric Lighting Systems, Business Department, Hendersonville, NC
111.	Stark, Jack H.	Public Works Department, Miami, FL
112.	Staubes, Michael S.	Police Department, Savannah, GA
113.	Stein, Harry A.	Department of Intergovernmental Fiscal Liaison, Milwaukee, WI
114.	Sternhell, Robert	Mayor's Criminal Justice Coordinating Council, New Orleans, LA
115.	Sullivan, Darcy	City Traffic Engineer, Knoxville, TN
116.	Turrek, Robert	Chicago Electric Institute, Chicago, IL
117.	Valenti, Sergeant	Crime Analysis Unit, Police Department, New York, NY
118.	Wachendorf, John	Department of Urban Development, Cincinnati, OH
119.	Waldner, Dudley	Edison Electric Institute, New York, NY
120.	Walsh, Joan	City Clerk, Manchester, NH
121.	Weiss, John	Office of Program Development, Boston, MA

	Name	Affiliation
122.	Welch, Betsy	Office of Justice Programs, Portland, OR
123.	Wright, Michael	Properties and Natural Resources Division, Arlington, MA
124.	Wright, Roger L.	Graduate School of Business Administration, University of Michigan, Ann Arbor, MI
125.	Yonemura, Gary T.	Center for Building Technology, National Bureau of Standards, Gaithersburg, MD
126.	Yule, James	Public Works Department, Kansas City, MO
127.	Zalkind, Alan	High Impact Anti-Crime Office, Newark, NJ
128.	Zotos, Michael	Mayor's Office, Baltimore, MD

APPENDIX B

LIGHT MEASURES

This appendix contains a somewhat technical but essential discussion of some light measures that are pertinent to an understanding of street lighting systems and their potential impact on crime.

Light is an electromagnetic field which oscillates periodically in both time and space. Light propagating in one direction and consisting of a single pure color (i.e., a monochromatic light beam) has a characteristic distance, called its wavelength, which is the length of the propagating light waves. Visible light consists of light with wavelengths ranging from 380 to 760 nanometers.* Normally, a field of light includes wavelengths in both the visible and invisible range, propagating in many directions at once. The light field anywhere within an area (e.g., a city street) is completely determined by (a) the light *sources* in the area, (b) the light transmitting and reflecting properties of the *media* (e.g., air, lenses, mirror, etc.) through which the light is propagating, and (c) the properties of the area's *boundaries* (e.g., street, building and sidewalk surfaces, etc.). Since the complete specification of a light field requires essentially an infinite amount of information, one selects only those parameters which are relevant to the task of

---

* A nanometer is 10^{-9} meter, or one-billionth of a meter.

interest. For a street lighting system that task is the visibility of people and objects.

The process of selecting the parameters relevant to the establishment of visibility by a street lighting system begins with a consideration of the total light output of the system, called *luminous flux*. Some of this light travels in directions relevant to the object to be viewed, while the rest goes elsewhere. Angular distribution is thus one relevant parameter dealing with quantity of light, and is measured for any direction by the *luminous intensity*. Light traveling in these various directions arrives at surfaces and *illuminates* them. When this light passes through or reflects from these surfaces, they acquire *brightness*, or *luminance*.

These measures of light quantity can be further refined by the notions of *uniformity*, *glare* and *color*, which are the elements of light quality. The *visibility* of an object is a function of the lighting quantity and quality, as well as of other factors in the environment, and is therefore considered following the discussion of the light measures themselves.

LIGHT QUANTITY

The measures of light quantity are summarized in Exhibit B.1. The total amount of radiant energy leaving a source in all directions

Exhibit B.1

Common Measures of Light Quantity

Measure	Definition	Common Unit	Unit Definition
Luminous Flux	Radiant energy per unit time	Lumen	Luminous flux of standard candle source ÷ 4π
Luminous Intensity	Luminous flux emitted per unit solid angle by a source	Candela	Luminous intensity of a spherically symmetric standard candle source
Illumination	Luminous flux incident per unit area on a given surface	Foot candle	One lumen per square foot
Brightness (Luminance)	Luminous flux emitted, transmitted or reflected per unit area by a source or surface	Foot lambert (or candela/in^2)	One lumen per square foot (or 452 foot lamberts)

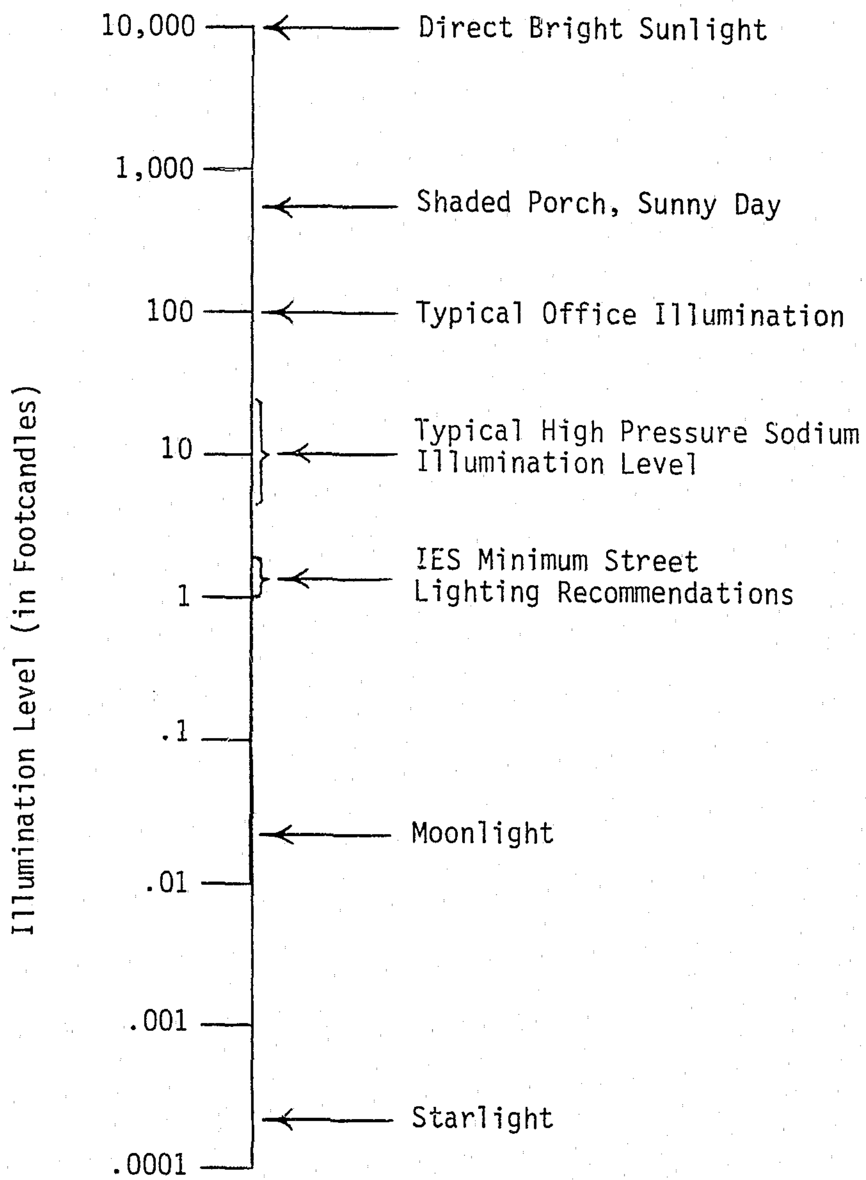
per unit time is known as *luminous flux*, and is measured in units of lumens. A standard candle source emits a total luminous flux of 4π (i.e., 12.57) lumens.

The luminous flux emitted by a source in a given direction is called *luminous intensity*, and is measured in units of candelas. A standard candle source emitting 4π lumens over a spherical region has an average luminous intensity in any given direction of one candela.

The effect of light arriving at a given surface is called illumination. *Illumination* measures the density of luminous flux arriving per unit area, and is measured in footcandles. An illumination of one footcandle is produced by an incident flux density of one lumen per square foot. Illumination is one of the most frequently used measures of street lighting: illumination of the horizontal roadway plane is the quantity specified in the minimum standards of the Illuminating Engineering Society of North America (IES) [A.2-59]. Some common illumination levels are given in Exhibit B.2. It should be noted that the range of illumination levels varies by a factor of 10^8, and that night street lighting illumination levels occupy a relatively small portion of this range, from one to ten footcandles. By its definition, illumination varies from point to point on any given plane. It is therefore common practice to define *average values* of illumination on a horizontal or vertical plane [A.2-26, A.2-59, A.2-60]. Roughly speaking, illumination in the horizontal plane lights the road

Exhibit B.2

Typical Illumination Levels



and sidewalk surfaces, while vertical illumination increases the visibility of people and objects.

The eye, however, does not directly perceive illumination in any plane except that of its own iris. What one sees is the light emitted, transmitted or reflected by the surfaces in the field of vision toward the eye. For surfaces which are not sources (i.e., for reflecting or transmitting surfaces) the combination of illumination and the surface's properties together result in the brightness of that surface. *Brightness* is defined as the luminous flux emitted, reflected or transmitted per unit area of a surface, and is measured in footlamberts (or candelas per square inch). A surface has a brightness of one footlambert when it emits one lumen per square foot. One candela per square inch equals 452 footlamberts. The term *luminance* is also used for brightness. Pavement brightness is of concern in street lighting systems, and in fact is used in the specification of minimum standards used by the International Commission on Illumination (CIE) [A.2-63]. The IES is expected to address the issue of luminance specification in its next revision of American National Standard Practice for Roadway Lighting. One issue which has impeded adoption of a luminance standard is that both luminaire performance and roadway reflectance data are required in order to design for a given luminance level. However, reflectance data is not generally available, and a given roadway's reflectance varies considerably with age, use and weather condition [A.2-36, A.3-78, A.3-106].

LIGHT QUALITY

The measures of light quality are summarized in Exhibit B.3. The first set of light quality measures is due to the fact that a street lighting system does not produce a uniform pattern of illumination or brightness, thus creating a need for measures of uniformity of varying detail. These measures include isocandela and isolux diagrams, uniformity, glare, and color.

The distribution of luminous intensity or illumination can be plotted on appropriate coordinate systems to produce contour maps showing the directions in space of equal luminous intensity or the loci of equal illumination on the horizontal roadway surface. Although an understanding of these detailed engineering tools, called *isocandela and isolux diagrams*, respectively, is not necessary for the present discussion, some simpler expressions of the uniformity of light can be helpful. With regard to roadway illumination and luminance, *uniformity ratio* is used to express the ratio of the average level to the minimum level, and both the IES and the CIE express limits on allowable uniformity ratios in their recommendations. According to the IES recommendations, illumination uniformity ratio should not exceed a ratio of 3 to 1, except for local residential streets, which should not have a ratio exceeding 6 to 1. The CIE recommendations apply to overall luminance uniformity and to longitudinal luminance uniformity [A.2-63]. The latter is defined as the ratio of the maximum to the minimum local luminance along the center line of the lane, as seen from an observation point on the

Exhibit B.3

Common Measures of Light Quality

Measure	Definition
Isocandela Diagram	Curves traced on an imaginary sphere with the source at the center and joining all points corresponding to those directions in which the luminous intensity is the same.
Isolux Diagram	The locus of all points on the road surface where the illumination has the same value.
Uniformity	
- Luminance Uniformity Ratio	
• Overall Luminance Uniformity	Ratio of average to minimum road surface luminance.
• Longitudinal Luminance Uniformity	Ratio of maximum to minimum local luminance along center line of lane, as seen from an observation point on the same line.
- Illumination Uniformity Ratio	Ratio of average to minimum illumination on a given surface.
- Roadway Luminance Gradient	Maximum luminance difference between two specified points, expressed as a percentage of the average luminance.
Glare	
- Disability Glare	Impairment of the ability to see due to harsh contrast between a luminaire and its background.

Exhibit B.3
(page 2 of 2)

Measure	Definition
- Disability Glare (continued)	
• Disability Veiling Brightness (DVB)	A function of illumination in the vertical plane at the eye, and of the angle between the line of sight and the glare source.
• Equivalent Veiling Luminance	A function similar to that used to calculate DVB.
• Disability Glare Factor (DGF)	A function of background and veiling luminance.
- Discomfort Glare	Discomfort due to harsh contrast between a luminaire and its background.
• Glare Control Mark	A function predicting a nine-point subjective discomfort index from lighting system characteristics.
Color	
- Spectral Energy Distribution	The relative energy emitted by a source as a function of wavelength.
- Color Temperature	The temperature at which an ideal black body spectrum most closely approximates a given source's spectrum.
- Correlated Color Temperature	The temperature at which the chromaticity of an ideal black body most nearly resembles that of a given source.
- Color Rendering Index	An index describing how well the colors of standard objects are rendered, relative to the performance of an ideal black body lamp of identical correlated color temperature.

same line.* Overall luminance uniformity is limited to a range of 1.4 or 2 to 1.

Gradient is an expression of the rate of change of a quantity in space, and *roadway luminance gradient* is defined as the maximum luminance *difference* between two specified locations, expressed as a percentage of the average luminance. No standards for gradient have been expressed by the illuminating engineering societies, but the measure has been held to be significant for clear perception and ease of recognition [A.2-107].

Glare refers to a condition of excessive brightness contrast, such as between a luminaire and its background. Two types of glare, disability and discomfort glare, have been discussed in the literature. *Disability, blinding,* or *veiling glare* refers to a condition in which the ability to see is impaired by the harsh contrast between a luminaire and its background. The effect of disability glare has been quantified by developing formulas which require measurement of such quantities as the luminance of the light source and its background, the illumination of the eye, and the angle between the line of sight and the glare source. The resulting quantities are called *disability veiling brightness, equivalent veiling luminance,* and *disability glare factor.* Their precise formulation is not required here, but the

---

* For convenience, the international definitions of uniformity, which are the reciprocal of the American indices, have been inverted to make comparison of the standards easier.

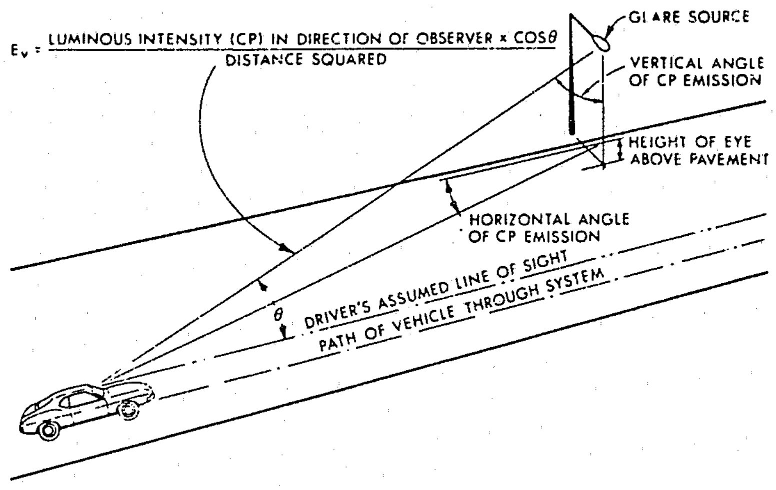
fact that they allow disability glare to be quantified should be noted. Exhibit B.4 illustrates the relationships of the quantities involved in measuring disability veiling brightness.

Discomfort glare is inherently subjective, and as such its measure requires an attitude survey which can, however, be correlated with the photometric and geometric characteristics of a lighting system. These correlations have been made experimentally, and one such index is the *glare control mark*. It has been found that a sensation of glare (i.e., glare control mark) on a 9-point scale from "unbearable" (with a score of 1) to "unnoticeable" (with a score of 9) can be predicted from a knowledge of certain system characteristics [A.2-63]. CIE recommendations require that the glare control mark be in the range of 4 to 6, depending on road type and brightness of the surrounding area.

Color rendering properties are important for several reasons, including recognition of faces and identification of clothing color. The subjective sensation of *color* can be correlated with the objective wavelength distribution, or spectral characteristic, of the light source. When the *spectral energy distribution* (*or spectrum*) of a light source is measured, a graph results, showing energy as a function of wavelength. Exhibit B.5 shows the sun's spectrum, which contains all visible wavelengths in approximately equal proportions--thus causing sunlight to appear as white, or colorless. The fact that light is the same entity as radio waves, ultraviolet waves, and other forms of electromagnetic radiation is also illustrated in Exhibit B.5, which shows the visible spectrum

Exhibit B.4

Measurement of Disability Veiling Brightness (DVB)



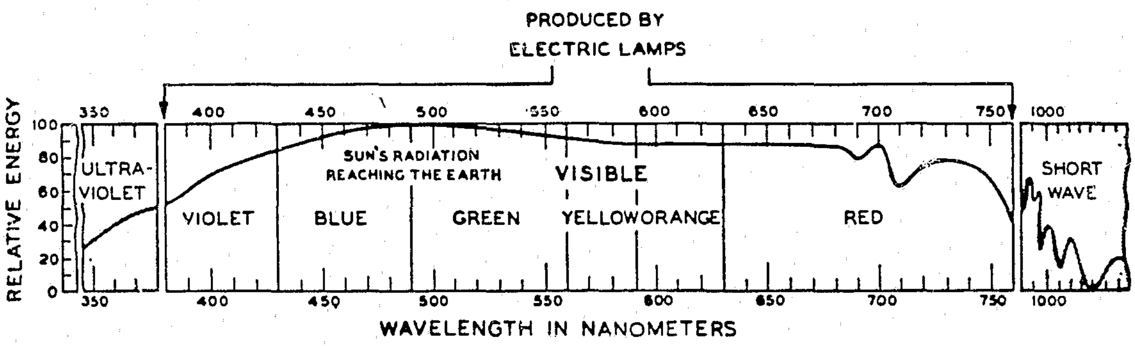
(a) Angular relationships for calculating DVB from one source and for one observer position.

(b) $$\text{DVB} = \frac{10\pi E_V}{\theta^2}$$

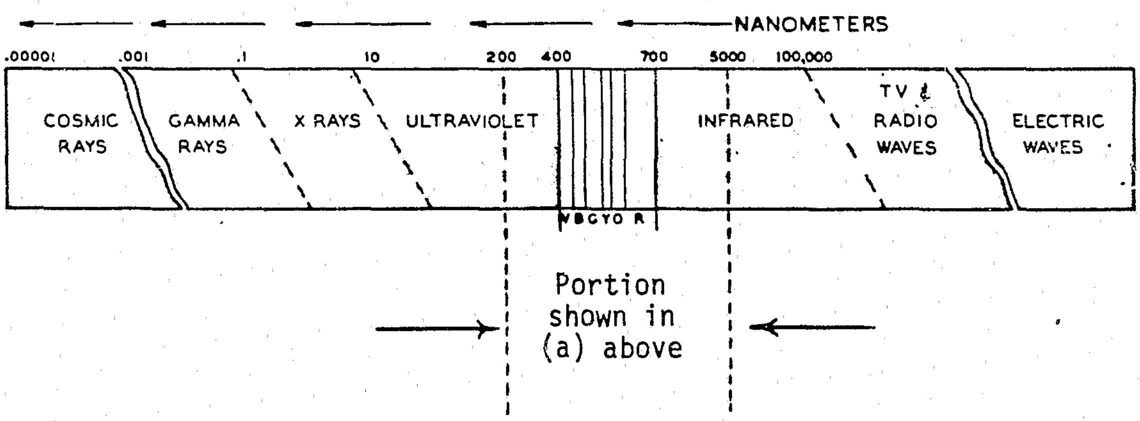
Source: American National Standard Practice for Roadway Lighting [A.2-59, p. 30].

Exhibit B.5

The Electromagnetic Spectrum



(a) Visible Spectrum



(b) Full Spectrum, Including Visible Portion

Source: Edison Electric Institute, Street Lighting Manual [A.2-26, p. 15].

CONTINUED

3 OF 4

in relation to phenomena associated with other wavelengths. Exhibit B.6 shows that the spectral distribution from an incandescent lamp is likewise continuous, and has the visible portion of its energy peak at the longer visible wavelengths, corresponding to red. In fact, extension of the graph in Exhibit B.6 to longer, invisible wavelengths would show that most of the energy of an incandescent bulb is radiated outside the visible range. This energy ultimately gets dissipated as heat. As the temperature of an incandescent bulb's filament increases, the spectrum changes shape to include relatively more energy in the shorter wavelengths (i.e., towards blue and green).

It is possible to approximate the spectrum of an incandescent bulb by an idealized spectrum known as a black body emission spectrum. This idealized spectrum is completely defined by one parameter: the hypothetical temperature of the ideal black body.* Thus, the best fit of an incandescent spectrum to the black-body curve results in the measurement of *color temperature*, the temperature at which an ideal black body would most closely approximate the spectrum of the given light source. Note that a bulb's color temperature does not equal its filament temperature, since the bulb is not a true black body.

High-intensity discharge lamps such as mercury vapor, metal-halide and high-pressure sodium do not have a continuous spectrum.

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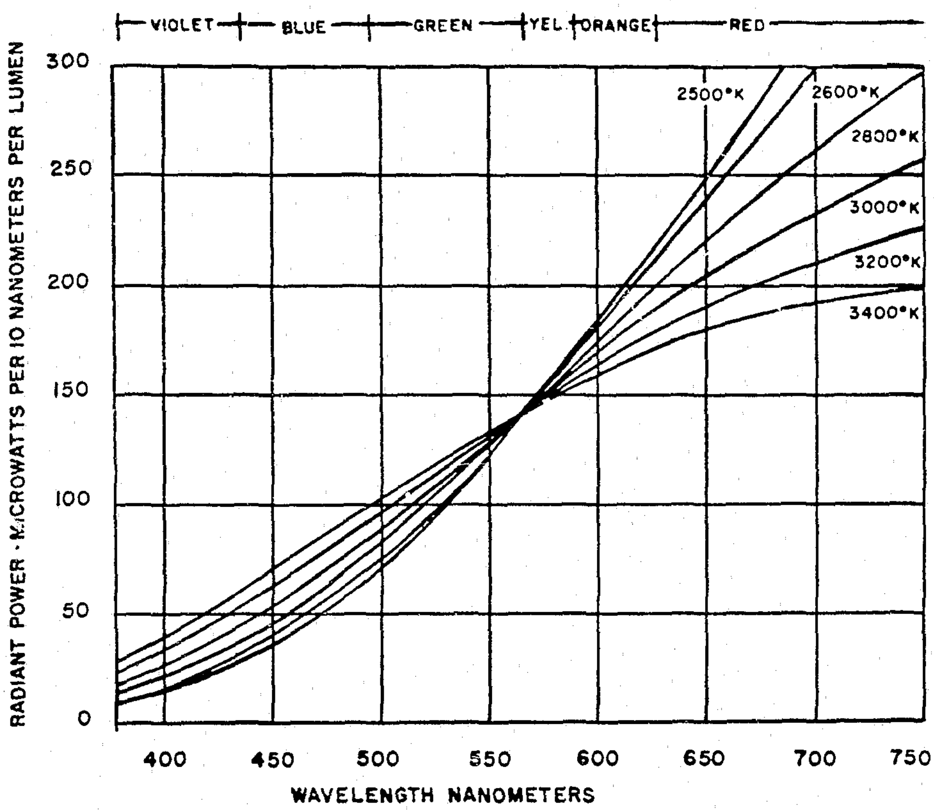
* An ideal black body is an object which absorbs all energy falling on its surface. Its characteristic black body emission spectrum, which is a function of temperature, is often used as a standard for comparison.

Exhibit B.6

Spectral Energy Distribution of an Incandescent Lamp at Various Filament Temperatures



Source: Edison Electric Institute, Street Lighting Manual [A.2-26, p. 113].

Their energy, as can be seen in Exhibit B.7, is concentrated in narrow ranges, or lines, and the distribution cannot be modelled by the black body curve. Hence, the use of color temperature as a measure of such a "line spectrum" is unwarranted. Nevertheless, there are still subjective responses to the spectra of gaseous discharge lamps for which some measure less cumbersome than an entire spectral distribution is required. One such measure, which is based on the spectrum itself, is *correlated color temperature*, which is the absolute temperature of that black body whose chromaticity most nearly resembles that of the light source [A.2-74]. However, sources with different line spectra and different color rendering properties can have the same correlated color temperature and for this reason the *color rendering index* is used. The index reflects how well the colors of standardized illuminated objects are rendered, relative to the performance of an ideal black body lamp of the same correlated color temperature [A.2-74].

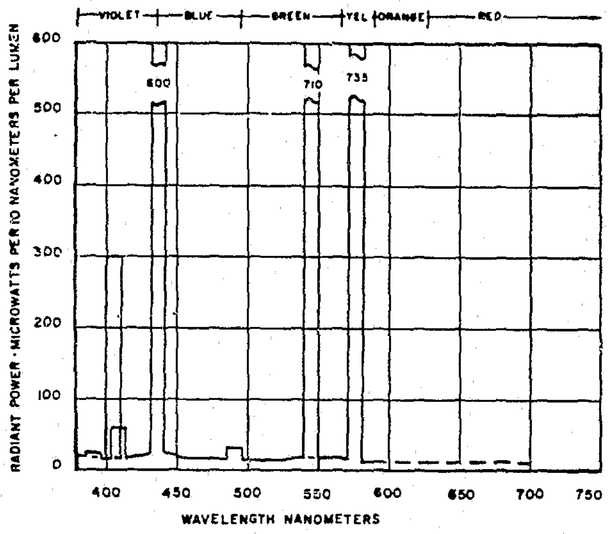
Finally, it should be noted that measures of light quality are highly interrelated. The American National Standard Practice for Roadway Lighting states [A.2-59, p. 14]:

> It should be recognized that in many instances changes intended to optimize one factor relating to quality will adversely affect another and the resultant total quality of the installation may be degraded.

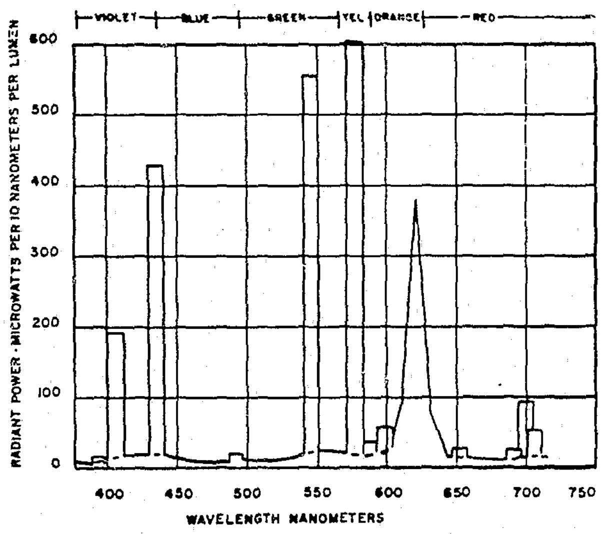
The problem of the illuminating engineer is to achieve a compromise among all relevant quality factors, based on the needs of the particular street lighting application.

Exhibit B.7

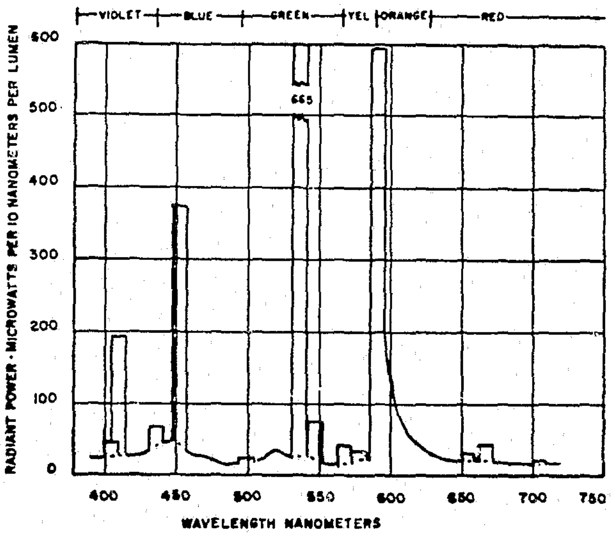
Spectral Energy Distributions of Principal Gaseous Discharge Lamps



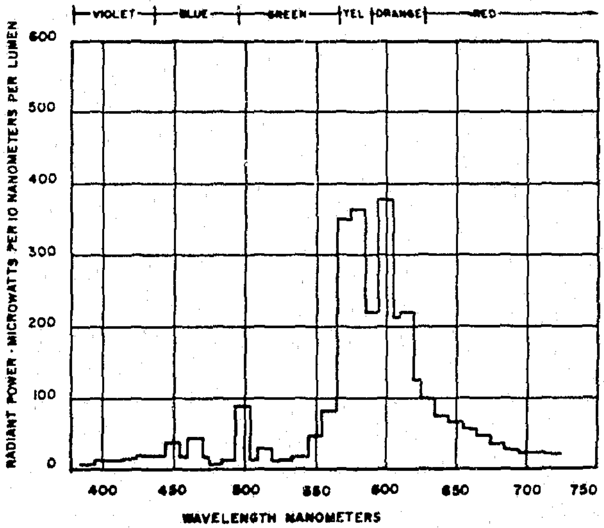
(a) Clear Mercury



(b) Deluxe White Mercury



(c) Metal Halide



(d) High-Pressure Sodium

Source: Edison Electric Institute, Street Lighting Manual [A.2-26, pp. 117-119].

VISIBILITY

Visibility is a concept which depends on a number of environmental factors, one of which is clearly the performance of the street lighting system. *Visibility is also a function of the particular object being viewed.* The critical factors entering into the determination of visibility have been summarized as [A.2-26, p. 70]:

1. *Size* of the object or its critical detail.
2. *Contrast* of the object and its background or in its complement parts.
3. *Brightness* of the object.
4. *Time* available for seeing or speed of vision.

Much of the research into the concept of visibility has taken a two-step approach: first, it is to determine with experimental subjects the relative visibility of specified objects under various lighting conditions, and then it is to find some physical measure that can predict visibility [A.2-9, A.2-36]. The objects which have been used in such tests range from mannequins and vehicles to discs, rings and cubes.

Meters have been developed for assessing the visibility of a given target in a given lighting environment [A.2-8, A.2-9]. These devices, employing laboratory scale models, require manipulation of the target's luminance or of the luminance contrast between the target and its background. Reduction of target visibility to a threshold level permits controlled comparisons between a test lighting system and some standard. Recent developments have extended controlled laboratory measurements to field conditions, and are based on those photometric measurements found by laboratory research to be the most relevant to the assessment of visibility.

One such recently-developed measure of visibility is the *visibility index* (VI) [A.2-36, A.2-66]. This measure has been used successfully to predict the visual performance of motorists in actual roadway environments. Further, the measured values of visibility index can be predicted from a knowledge of the characteristics of a street lighting system and the roadway surface. Thus, a basis exists for linking street lighting system characteristics with successful performance by motorists of tasks relevant to traffic safety [A.2-36, A.2-66].

The remainder of this section discusses the definition, measurement and prediction of the visibility index, and briefly reviews the results establishing a relationship between visibility index and traffic safety requirements. Visibility index (VI) has been defined as [A.2-36, A.2-66]:

$$VI = C \cdot (RCS_{L_b}) \cdot DGF,$$

where

C = absolute value of target-to-background luminance contrast,

RCS_{L_b} = relative contrast sensitivity of motorists adapted to background luminance level L_b, and

DGF = disability glare factor.

Thus, the visibility of a target is given by the contrast (C) between its luminance and the background luminance, corrected for the fact that the eye's sensitivity to contrast varies with its adaptation to the background roadway luminance level (RCS), and for the disability effects of direct glare from the luminaires (DGF). All of the above parameters can be calculated from formulas involving target, roadway and luminaire luminance and existing empirical tables of relative contrast sensitivity. The standard target used in the definition of VI is the bottom 18 inches of a standard American traffic cone, painted to a specific reflectance value.

Experiments have shown that VI can also be predicted by calculating the required luminances from input information on the roadway and the street lighting configuration [A.2-66]. VI has also been found to be closely correlated with the distance at which motorists first attempt stopping to avoid the target [A.2-36]. Efforts now underway indicate that VI can serve to predict observed accident rates in locations with different lighting conditions. Analysis of these data will be used to guide the development of street lighting specifications which directly address traffic safety [A.2-66]. The possibility of using a modified definition of visibility index in evaluations of the impact of street lighting on crime is discussed in Section 2.2.

APPENDIX C

SURVEY INSTRUMENTS

As part of the data collection effort, three broad surveys were undertaken. First, 65 LEAA State Planning Agencies and Regional Offices were surveyed in an effort to solicit information regarding street lighting and crime; the survey instrument is reproduced in Exhibit C.1. As a note of interest, 31 out of 65 agencies and offices responded, and 16 of the responses contained pertinent information.

The second and third surveys (i.e., the telephone interview and site visit surveys) used the same survey instrument, which is reproduced in Exhibit C.2. As noted in Section 1.2, telephone interviews were conducted of 60 street lighting projects, and site visits were made to 17 project sites.

Information Survey Instrument

Public Systems Evaluation, Inc.

R. C. Larson, Ph.D., President
J. M. Tien, Ph.D., Executive Vice President
G. C. Larson, Vice President & Treasurer
K. W. Colton, Ph.D., Vice President

June 9, 1976

As you may know, Public Systems Evaluation, Inc. (PSE) was recently awarded a National Evaluation Program (NEP) grant by NILECJ, entitled "Phase I Evaluation of Street Lighting Projects" (Grant Award #76NI-99-0090). The object of this letter is to state the purpose and scope of the grant and to enlist your cooperation in this important effort.

In brief, the purpose of the grant is to assess the present state of knowledge regarding the impact of street lighting on crime and the fear of crime. To this end, PSE will undertake an encompassing assessment of street lighting projects through review of available literature, investigation of existing projects, discussions with lighting experts, development of a measurement model (evaluation framework), and the subsequent systematic analysis of this accumulated knowledge base. The assessment will determine the range of performance and effectiveness of various street lighting projects, the accuracy and reliability of available data in the street lighting area, the factors that seem most likely to influence the success or failure of projects, and the cost of implementing and maintaining alternative types of street lighting projects/systems. Utilizing this information, PSE will be able to identify gaps in the present knowledge base and make recommendations concerning future research and evaluation activities which should be undertaken to fill those gaps.

We hope that the above description of the grant will enable you to provide us with copies of pertinent reports, studies, or projects that have been funded and/or reviewed by your office. Also, please advise us if you would like to designate someone on your staff other than yourself to serve as our contact person. A response form is enclosed for your convenience.

Please do not hesitate to write or call me should you desire any additional information. Thanking you in advance for your cooperation.

Sincerely,

James M. Tien, Ph.D.
Project Director

JMT/epk

929 Massachusetts Avenue, Cambridge, Massachusetts 02139 617/547-7620

TO: Dr. James M. Tien
Public Systems Evaluation, Inc.
929 Massachusetts Avenue
Cambridge, Massachusetts 02139

In support of the "Phase I Evaluation of Street Lighting Projects," I am enclosing the following documents for your review:

1.
2.
3.
4.

I would also recommend the following documents and/or on-going programs that you should review:

1.
2.
3.
4.

For further information, please contact (Mr./Ms.) ____________________:

(he/she) can be reached at the following number ____________________.

Sincerely,

____

(Title) ____________________

Exhibit C.2

Telephone Interview and Site Survey Instrument

Public Systems Evaluation, Inc.

PHASE I EVALUATION OF STREET LIGHTING PROJECTS
SURVEY INSTRUMENT: TELEPHONE INTERVIEW AND SITE VISIT

Control No. ____ Location ________ Interviewer ________

Site Visit ☐ Telephone Interview ☐

Date	Respondent Name	Time Scheduled	Time Start	Time Stop	Call-Back? (Check if Yes)
____	________	________	____	____	☐
____	________	________	____	____	☐
____	________	________	____	____	☐
____	________	________	____	____	☐

(BEFORE BEGINNING THE INTERVIEW, ENTER FROM PSE FILES THE INFORMATION REQUESTED IN THOSE QUESTIONS WHICH ARE MARKED WITH AN ASTERISK IN THE MARGIN.)

	Designated	Corrected
* Respondent:	________	________
* Title:	________	________
* Department, Agency:	________	________
* City:	________	________
* Telephone:	________	________

929 Massachusetts Avenue, Cambridge, Massachusetts 02139 617/547-7620

1 INTRODUCTION

Hello, my name is ________________. I am calling for Public Systems Evaluation in Cambridge, Massachusetts. We are a private, not-for-profit research firm. Recently, we were funded by the Law Enforcement Assistance Administration to conduct a study on street lighting and crime. I am calling to get some information
* on the (NAME OR DESCRIPTION OF PROJECT) ________________
* that was implemented in (YEARS) ________________. The kind of information I am looking for includes 1) a description of the project itself, 2) a review of related activities that may have affected the project's impact on crime, and 3) a summary of the evaluation findings, if such an evaluation was conducted.

1.1 Would you be able to speak to me now about this?

☐ YES, NOW (GO TO QUESTION 1.2)

☐ YES, AT A DIFFERENT TIME (ENTER CALL-BACK TIME ON PAGE 1)
Thank you. I look forward to talking with you then.

☐ NO, REFERRED TO ANOTHER PERSON.

REFERRED TO:

Name: ________________

Title: ________________

Department, Agency, etc.: ________________

Telephone: ________________

I will follow up with him/her. Thank you for the information. (ENTER NEW RESPONDENT'S NAME ON PAGE 1)

(continued)

☐ NO. If you are aware of any studies, reports or evaluations or any other information relevant to street lighting and crime, I would appreciate your contacting me at (GIVE PSE ADDRESS AND TELEPHONE AND REPEAT NAME). Thank you for your time.

1.2 First, I want to be sure that I have your name, title and agency listed correctly. (RE-READ RESPONDENT'S NAME AND NOTE ANY CORRECTIONS.)

1.3 I would also like to verify some information in our files concerning this project. (READ INFORMATION IN LEFT-HAND COLUMN BELOW AND NOTE ANY CORRECTIONS.)

	Designated	Corrected
Project Name	______________	______________
	______________	______________
Project Number	______________	______________
	______________	______________
(IF INCOMPLETE) Expected Date of Completion	______________	______________

(IF MAJOR DISCREPANCIES APPEAR, INQUIRE ABOUT LIGHT SOURCE TYPE, TARGET AREA, FUNDING SOURCES AND DATES TO BE SURE RESPONDENT UNDERSTANDS WHICH PROJECT YOU ARE REFERRING TO, OR TO VERIFY EXISTENCE OF PROJECT)

2 PROJECT DESCRIPTION

Now, I want to ask a series of questions about the project, covering its organization, funding, objectives, target area, equipment, performance, maintenance and operation.

2.1 Organization

2.1 (a) Who owns, and who maintains the street lighting system which has been implemented in this project? (CHECK BOX(ES) THAT APPLY. IF TWO ARE CHECKED, INDICATE THE APPROXIMATE PERCENTAGES PERTAINING TO EACH CHECKED BOX)

		Maintenance	
		Municipality	Utility
Ownership	Municipality		
	Utility		

2.1 (b) Which agencies were involved in planning, implementing, and operating this project, and what were their respective function(s) and relationship(s) to each other?

Agency Name	Function(s)	Relationship(s) to Other Agencies
________	________	________
	________	________
	________	________
________	________	________
	________	________
	________	________
________	________	________
	________	________
	________	________
________	________	________
	________	________
	________	________

2.2 Funding

2.2 (a) What are the sources and amounts of funds for this project?

☐ FEDERAL GOVERNMENT (AGENCY NAME) ____________
(AMOUNT) ____________

☐ LOCAL GOVERNMENT (DEPARTMENT NAME) ____________
(AMOUNT) ____________

Is that amount from
☐ OPERATING BUDGET
☐ NORMAL CAPITAL BUDGET
☐ SPECIAL BOND ISSUE
☐ PRIVATE SECTOR (SOURCE NAME) ____________
(AMOUNT) ____________

2.2 (b) I want to find out how these project funds were used. Were any funds included in the total you gave above used for:

Planning and system design? ☐ YES (AMOUNT) ____________ ☐ NO

(IF MUNICIPALLY-OWNED)
Purchase and installation of equipment? ☐ YES (AMOUNT) ____________ ☐ NO

(IF MUNICIPALLY-OWNED)
Operation and maintenance? ☐ YES (AMOUNT PER YEAR) ____________ ☐ NO

(IF UTILITY-OWNED)
Utility company installation charges or penalties? ☐ YES (AMOUNT) ____________ ☐ NO

(continued)

(IF UTILITY-OWNED)
Leasing of system from Utility Company? ☐ YES (AMOUNT PER YEAR) ____________ ☐ NO

Other uses? ☐ YES (SPECIFY USES AND AMOUNTS) ____________ ☐ NO

2.3 Objectives

2.3 (a) What, specifically, were the goals of this project? (PROBE FOR MEASURABLE OBJECTIVES WITHIN EACH GOAL AREA)

Goal Area	Objectives
G1. Impact Goal: Security and safety	G1.1 ____________ G1.2 ____________ G1.3 ____________
G2. Impact Goal: Community character and vitality	G2.1 ____________ G2.2 ____________ G2.3 ____________
G3. Impact Goal: Traffic orientation and identification	G3.1 ____________ G3.2 ____________ G3.3 ____________
G4. Other Process Goals: (e.g., energy considerations...) (SPECIFY) ____________	G4.1 ____________ G4.2 ____________ G4.3 ____________

2.3 (b) Was there any conflict between different objectives of the street lighting program?

☐ YES (WHICH OBJECTIVES) ____________
(TYPE OF CONFLICT(S)) ____________
(HOW RESOLVED) ____________
☐ NO
☐ DON'T KNOW

2.4 Target Area(s)

2.4 (a) What are the sizes of the areas covered by this project?

Area Name	Size (INDICATE UNIT OF MEASURE)
1. ____________	______________________
2. ____________	______________________
3. ____________	______________________
4. ____________	______________________

2.4 (b) Does this project consist of area-wide or arterial lighting? (CHECK AS MANY AS APPLY)

- ☐ AREA-WIDE
- ☐ ALLEYS
- ☐ ARTERIAL
- ☐ DON'T KNOW

2.4 (c) What is the land use in the project target area(s)? (CHECK AS MANY AS APPLY)

- ☐ CENTRAL BUSINESS DISTRICT (CBD)
- ☐ RESIDENTIAL
- ☐ COMMERCIAL (OTHER THAN CBD)
- ☐ INDUSTRIAL
- ☐ PARKS OR PUBLIC BUILDINGS
- ☐ FREEWAYS, INTERSTATE HIGHWAYS
- ☐ CITY-WIDE-ALL USES
- ☐ OTHER (SPECIFY) ______________________

2.4 (d) What was the procedure and which agencies were involved in selecting the target area(s)? (PROBE FOR AGENCY RESPONSIBLE FOR FINAL DECISION)

____

____

____

2.4 (e) What criteria (e.g. high crime, political commitment...) were used in the selection of the target area(s)?

____

____

____

2.5 Equipment

2.5 (a) I would like to know what equipment was removed and/or installed by this project. First, can you give me the types and sizes of the lights removed? Then I'll ask for specific information on each type. (RECORD EACH TYPE AND SIZE; THEN DETERMINE NUMBER, MOUNTING HEIGHT, TYPICAL SPACING, TYPICAL ARRANGEMENT, LIGHT DISTRIBUTION TYPE, CUT-OFF CHARACTERISTIC, AND NUMBER OF POLES REMOVED)

Lamp Type						
Lamp Size:						
Watts						
Initial Lumens						
Number of lamps removed						
Mounting Height(s) (Feet)						
Typical Spacing (Feet)						
Typical Arrangement						
One-sided						
Opposite						
Staggered						
Center-opposite						
Light Distribution Type (I through V)						
Cut off Characteristic						
Full						
Semi						
Non						
Number of Poles Removed						

2.5 (b) Now, what were the types and sizes installed? (IF MOUNTING HEIGHT, SPACING, OR ARRANGEMENT WERE UNCHANGED, ENTER "NC" AND ENTER, ON "CHANGEOUT FROM" LINE, THE SIZE AND TYPE OF LAMP REPLACED)

Lamp Type						
Lamp Size: Watts						
Initial Lumens						
Number						
Mounting Heights (Feet)						
Typical Spacing (Feet)						
Typical Arrangement One-sided						
Opposite						
Staggered						
Center-opposite						
Light Distribution Type (I through V)						
Cut off Characteristic Full						
Semi						
Non						
Number of Poles Installed						
Changeout from:						

2.5 (c) Which agencies were involved in determining the equipment required? (PROBE FOR AGENCY RESPONSIBLE FOR FINAL DECISION)

____
____
____

2.5 (d) Which criteria were used to determine the equipment required? (PROBE FOR EQUIPMENT OR COST CONSTRAINTS AS WELL AS FOR OTHER CRITERIA)

____
____
____

2.5 (e) (IF MUNICIPALLY-OWNED) Who installed the system?

- ☐ CITY DEPARTMENT (SPECIFY) ____________________
- ☐ CONTRACTOR
- ☐ UTILITY COMPANY

2.5 (f) What was the installation period?

From ________________ to ____________________.

2.5 (g) What problems, if any, were encountered in performing installation work according to specifications?

- ☐ NONE
- ☐ INTERNAL PROBLEMS:
  - ☐ ADMINISTRATIVE DELAYS
  - ☐ OMISSION OF REQUIRED COSTS OR ELEMENTS FROM SPECIFICATIONS
  - ☐ CHANGING LOCAL CODES
  - ☐ ENVIRONMENTAL IMPACT STATEMENT REQUIREMENTS
  - ☐ HISTORIC PRESERVATION REQUIREMENTS
  - ☐ OTHER (SPECIFY) ____________________
  ____

(continued)

☐ EXTERNAL PROBLEMS:

- ☐ EQUIPMENT, MATERIAL QUALITY
- ☐ EQUIPMENT, MATERIAL AVAILABILITY
- ☐ REGULATION OF UTILITY COMPANY
- ☐ INFLATION COST OVERRUN
- ☐ LABOR DISPUTE
- ☐ VANDALISM
- ☐ OTHER (SPECIFY) ______________________________

2.5 (h) How were these difficulties resolved?

____
____
____

2.6 Performance

2.6 (a) How do the project's performance specifications compare with the American National Standard Practice for

	DON'T KNOW	NOT SPECIFIED	DOES NOT MEET	MEETS	EXCEEDS
Average street illumination?	☐	☐	☐	☐	☐
Street uniformity ratio?	☐	☐	☐	☐	☐
Average sidewalk illumination?	☐	☐	☐	☐	☐
Sidewalk uniformity ratio?	☐	☐	☐	☐	☐

2.6 (b) Are any other light parameters included in the performance specifications?

- ☐ NO
- ☐ YES:
  - ☐ ROADWAY LUMINANCE
  - ☐ VERTICAL ILLUMINATION
  - ☐ GLARE
  - ☐ COLOR
  - ☐ VISIBILITY
  - ☐ OTHER (SPECIFY) ______________________________

2.6 (c) Which agencies were involved in determining the performance specifications? (PROBE FOR AGENCY RESPONSIBLE FOR FINAL DECISION)

____
____

2.6 (d) What performance characteristics, if any, have you actually verified in the field?

- ☐ NONE
- ☐ HORIZONTAL ILLUMINATION
- ☐ UNIFORMITY
- ☐ OTHER (SPECIFY) ______________________________

2.6 (e) When has actual performance been measured?

- ☐ AFTER CONSTRUCTION OR CHANGEOUT
- ☐ REGULAR INTERVALS, EVERY ______ YEARS
- ☐ ON COMPLAINT
- ☐ OTHER (SPECIFY) ______________________________

2.6 (f) Is performance measured over the whole target area or on a sample of locations?

- ☐ AREA-WIDE
- ☐ SAMPLE (SPECIFY) ____________________

2.6 (g) How is it verified?

- ☐ VISUAL INSPECTION, UNINSTRUMENTED
- ☐ INSTRUMENTED MEASUREMENT (SPECIFY INSTRUMENTS) __________
____

2.7 Maintenance

2.7 (a) (IF MUNICIPALITY IS RESPONSIBLE FOR MAINTENANCE) Who performs the maintenance of the system?

- ☐ CITY DEPARTMENT (SPECIFY) ____________________
- ☐ CONTRACTOR

2.7 (b) How are lamp replacement and luminaire cleaning scheduled?

	ON COMPLAINT	SPOT CHECK	PERIODICALLY	INTERVAL (SPECIFY)
Lamp Replacement	☐	☐	☐	______
Luminaire Cleaning	☐	☐	☐	______

2.7 (c) Now, I would like to get the annual unit operating cost for each separate lamp type.

Type	____	____	____	____	____	____
Watts	____	____	____	____	____	____
Lumens	____	____	____	____	____	____
Annual Energy Cost	____	____	____	____	____	____
Annual Maintenance Cost . .	____	____	____	____	____	____
Other Operating Cost	____	____	____	____	____	____

(continued)

Annual Lease Rate	____	____	____	____	____	____
Total Annual Cost	____	____	____	____	____	____

(IF ONLY TOTAL ANNUAL COST IS AVAILABLE, CHECK THE SUB CATEGORIES WHICH ARE INCLUDED, E.G., ANNUAL ENERGY COST ONLY, OR ENERGY AND MAINTENANCE)

3 RELATED ACTIVITIES

Now, I have a series of questions about some related activities that could affect a street lighting project's performance or its impact on crime.

3.1 Interventions

I want to check if other interventions were planned jointly with the street lighting intervention or took place in the same area or time period:

	INTERVENTION	PLANNED JOINTLY	IMPLEMENTED JOINTLY
I.1	Other street lighting	☐	☐
I.2	Urban Renewal	☐	☐
I.3	Model Cities	☐	☐
I.4	Police Patrol Experiment	☐	☐
I.5	Impact Cities	☐	☐
I.6	TOPICS	☐	☐
I.7	Other signs or signals	☐	☐
I.8	Tree planting or pruning	☐	☐
I.9	Code enforcement	☐	☐
I.10	Other law enforcement (SPECIFY) __________	☐	☐

(continued)

INTERVENTION	PLANNED JOINTLY	IMPLEMENTED JOINTLY
1.11 Other physical planning (SPECIFY) ________	☐	☐
1.12 Other human services (SPECIFY) ________	☐	☐
1.13 None	☐	☐

(IF ANY BOXES WERE CHECKED, PROBE FOR DETAILS: TIME, PLACE, DESCRIPTION AND MAGNITUDE OF INTERVENTION)

INTERVENTION	DESCRIPTION
________	________
	________
	________
________	________
	________
	________
________	________
	________
	________
________	________
	________
	________

3.2 Energy Considerations

3.2 (a) During the 1973-1974 energy crisis, or at any other time, was light output or energy use of the system reduced because of the availability or cost of energy?

☐ YES
☐ NO (GO TO 3.3)
☐ DON'T KNOW

3.2 (b) What was the reason for the reduction?

☐ SUPPLY
☐ COST
☐ OTHER (SPECIFY) ________
☐ DON'T KNOW

3.2 (c) What was done as part of the reduction effort?

	Horizontal Roadway Illumination		
	Increased	Maintained	Decreased
Increased lamp efficacy, replaced luminaire	☐	☐	☐
Increased lamp efficacy, "nonretrofit" lamp, same luminaire	☐	☐	☐
Increased lamp efficacy, "retrofit" lamp, same luminaire	☐	☐	☐
Reduced lamp wattage, no increased efficacy	☐	☐	☐
All lamps off	☐	☐	☐
Other (SPECIFY) ________	☐	☐	☐

3.2 (d) In what kinds of area and street type was the reduction in effect?

Area	Street Type
________	________
________	________
________	________

3.2 (e) During what period was this reduction in effect?

From ________
To ________

3.2 (f) (IF ILLUMINATION WAS REDUCED--OTHERWISE, GO TO QUESTION 3.3)

Was data collected during the reduction of illumination on changes in crime?

☐ YES (SPECIFY) ______________________
☐ NO
☐ DON'T KNOW

3.3 Vegetation Considerations

3.3 (a) Beginning with some experiments reported by Dr. Marc Cathey of the Agricultural Research Center in Beltsville, Maryland, there has been some question about possible harmful effects of street lighting on plant life. Do you feel that street lights affect vegetation seriously enough for this to be taken into account when writing specifications?

☐ YES
☐ NO
☐ DON'T KNOW

3.3 (b) Why is that?

____
____
____

3.4 Legal Considerations

3.4 (a) Does your jurisdiction have a building security ordinance requiring property owners to light their buildings?

☐ EXTERIOR
☐ INTERIOR--STOREFRONTS
☐ INTERIOR--HALLS

(continued)

☐ OTHER (SPECIFY) ______________________
____
☐ NONE OF THE ABOVE
☐ DON'T KNOW

3.4 (b) Has your jurisdiction been involved in any civil litigation involving street lighting and crime occurrence?

☐ GEOGRAPHICAL ALLOCATION OF STREET LIGHTING RESOURCES
☐ MAINTENANCE OF STREET LIGHTING
☐ DESIGN OF STREET LIGHTING
☐ OTHER (SPECIFY) ______________________
☐ NONE OF THE ABOVE
☐ DON'T KNOW

4 EVALUATION-RELATED INFORMATION

4.1 Background

*4.1 (a) Has an evaluation been conducted to assess the impact of this project on crime or the fear of crime?

☐ YES, COMPLETED (REQUEST A COPY IF NOT ON FILE ALREADY)
☐ YES, IN PREPARATION (REQUEST A COPY)
(EXPECTED COMPLETION DATE) ______________________
☐ NO (GO TO SECTION 5)

*4.1 (b) Who was/is the evaluator?

NAME ______________________
AGENCY ______________________

*4.1(c) To whom did/does the evaluator report?

NAME ______________________
AGENCY ______________________

*4.1 (d) Does/Will the evaluation address the impact of street lighting on:

	YES	NO
Crime?	☐	☐
Attitude/Fear?	☐	☐
Behavior?	☐	☐

Now, I would like to ask you a series of questions concerning the objectives addressed by the evaluation, the evaluation design and the evaluation results.

4.2 Evaluation Objectives

4.2 Earlier, you described the project's objectives as (READ BACK RESPONSE TO QUESTION 2.3(a)). Which of these objectives does the evaluation address, and how are they stated for the purposes of the evaluation?

Objective	Evaluation Statement
______________	______________
______________	______________
______________	______________

4.3 Evaluation Design

4.3 (a) Turning now to the evaluation design, what procedures were used for defining control or displacement areas?

____

____

4.3 (b) For sampling and randomization?

____

4.3 (c) Over what time intervals were the data collected?

____

4.3 (d) What procedures were used for statistical comparisons and analyses?

____

4.3 (e) What statistical significance tests were applied?

____

4.3 (f) (IF OTHER INTERVENTIONS ARE INDICATED IN QUESTION 3.1) How does the evaluation account for the impact of (NAME OF INTERVENTION(S)) _______________?

____

4.4 Evaluation Results

4.4 (a) What light parameters were used in the evaluation?

	MEASURED	DESIGNED
Horizontal illumination--street	☐	☐
Horizontal illumination--sidewalk	☐	☐
Uniformity ratio--street	☐	☐
Uniformity ratio--sidewalk	☐	☐
Other photometric variables (SPECIFY) ________________	☐	☐
Light source type (high pressure sodium, etc.)	☐	☐
Light source lumen output	☐	☐
Relit/Non-relit	☐	☐
Other (SPECIFY) ______________	☐	☐

4.4 (b) (IF CRIME IMPACT IS ASSESSED--OTHERWISE GO TO QUESTION 4.4(e)) What indicators were used for assessing crime in the evaluation? (CHECK AS MANY AS APPLY)

- ☐ REPORTED CRIME
- ☐ VICTIMIZATION
- ☐ ARRESTS
- ☐ OTHER (SPECIFY) ________________________________

4.4 (c) What were the target crime changes?

	CHANGE	PERIOD OF COMPARISON	STATISTICALLY SIGNIFICANT?
MURDER			
RAPE			
ROBBERY			
ASSAULT			
BURGLARY			
LARCENY			
AUTO THEFT			

(continued)

	CHANGE	PERIOD OF COMPARISON	STATISTICALLY SIGNIFICANT?
VANDALISM			
OTHER (SPECIFY) ______			

4.4 (d) What breakdowns are given in the crime data for:

Time of day? ________________________

Outdoor (Street)/
Indoor (Nonstreet)? ________________________

Target Area Type? ________________________

4.4 (e) (IF ATTITUDE IMPACT OR VICTIMIZATION WAS ASSESSED--OTHERWISE GO TO QUESTION 4.4 (i).)

In the attitude/victimization study, what population was surveyed?

	# INTERVIEWS ATTEMPTED	# OF RESPONSES
☐ RESIDENTS		
☐ GENERAL STREET USERS		
☐ BUSINESSES		
☐ POLICE		
☐ OTHER (SPECIFY)		
____________		
____________		

4.4 (f) How was the survey conducted?

- ☐ TELEPHONE
- ☐ IN-PERSON--AT HOME
- ☐ IN-PERSON--OTHER LOCATION (SPECIFY) ____________________
- ☐ MAILED WRITTEN QUESTIONNAIRE

4.4 (g) (IF EVALUATION QUESTIONNAIRE NOT ON FILE AT PSE)

Can you send me a copy of the questionnaire used in the attitude/ victimization study?

- ☐ YES (GIVE PSE MAILING ADDRESS)
- ☐ NO

4.4 (h) (ATTITUDE STUDIES ONLY)

Which attitudinal measures changed?

	CHANGE	PERIOD OF COMPARISON	STATISTICALLY SIGNIFICANT?
PERCEIVED SECURITY	______	______	______
PERCEIVED CRIME LEVEL	______	______	______
PERCEIVED NIGHT STREET USE	______	______	______
RESPONDENT'S CHANGE IN NIGHT STREET USE	______	______	______
PERCEIVED POLICE EFFECTIVENESS	______	______	______
APPROVAL OF THE STREET LIGHTING	______	______	______

4.4 (i) (IF IMPACT ON BEHAVIOR WAS ASSESSED)

What behavioral measures were made and how did they change?

____

____

____

4.4 (j) In terms of the target area(s), could you give me the following data?

SIZE OF TARGET AREA ______________________

POPULATION ______________________

DEMOGRAPHICS ______________________

LAND USE ______________________

SOCIOECONOMIC MEASURES ______________________

5 CONCLUSION

5.1 Do you think street lighting affects crime and/or the fear of crime?

- ☐ YES - CRIME
- ☐ YES - FEAR
- ☐ YES - BOTH
- ☐ DON'T KNOW, NOT SURE
- ☐ NO

5.2 (IF YES)

In what ways? ______________________________________

____

____

5.3 If you were to have another street lighting project with similar objectives, would you change the planning, operation or evaluation process in any manner?

☐ YES In what manner? ______________________________

____

____

☐ NO

5.4 What aspects of this project's planning, operation or evaluation do you feel can serve as a model for other similar projects?

____

____

____

5.5 We will be looking at the actual data more closely in a series of on-site visits to selected locations. Would a visit to (NAME OF CITY) to view the project and examine the available data more closely be possible sometime in the next few weeks?

- ☐ YES. We may be in touch in the very near future.
- ☐ NO
- ☐ DEPENDS ON (SPECIFY) ______________________________

____

5.6 Is there anyone else with whom I can talk for additional information about other street lighting projects and their impact on crime?

NAME	AGENCY	TELEPHONE	TYPE OF INFORMATION

5.7 Do you have any other comments you would like to make?

____

____

____

On behalf of Public Systems Evaluation, I would like to thank you for your time and patience in answering these questions. Have a pleasant day.

END