Series A
Number 21

NATIONAL EVALUATION PROGRAM

Phase I Report

Street Lighting Projects

National Institute of Law Enforcement and Criminal Justice
Law Enforcement Assistance Administration
U. S. Department of Justice

NATIONAL EVALUATION PROGRAM
Phase I Report

Street Lighting Projects

James M.Tien
Principal Investigator
Vincent F. O'Donnell
Arnold Bamett
Pitu B. Mirchandani

January 1979

National Institute of Law Enforcement and Criminal Justice
Law Enforcement Assistance Administration
U. S. Department of Justice

Law Enforcement Assistance Administration
Henry S. Dogin, Acting Administrator
National Institute of Law Enforcement and Criminal Justice
Blair G. Ewing, Acting Director

This project was supported by Grant Number 76-NI-99-0090, awarded to Public Systems Evaluation, Inc. by the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice, under the Omnibus Crime Control and Safe Streets Act of 1966, as amended. Points of view or opinions stated in this document are those of the authors and do not necessarily represent the official position or policies of the U.S. Department of Justice.

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 tike 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

TABLE OF CONTENTS

LIST OF EXHIBITS

1 INTRODUCTION

Is street lighting an effective approach in the reduction and deterrence of crime? In 1967, the President's Crime Commission stated that [1]*:

> 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 [2]:

> ...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 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

---

* For convenience, all references in this report are sequentially numbered and identified in the last section of the report.

** 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.

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 [3,4].

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 provide a timely, objective and reliable assessment of selected topic areas which have received substantial LEAA funding. 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. [5], 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 summarizes the impact-oriented objectives of street lighting systems; they have

Exhibit 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

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 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 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.

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 3; it consists essentially of seven tasks.

* An abbreviated, technical discussion of light measures is contained elsewhere—In Appendix B of the Final Report. In any analysis 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 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
H33-1C0/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
	19S2	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
Mgh-Pressure Sodium			
	1965	6,000 hours	Over 100
	1975	15,000 hours	140

(a) Electric Street Lighting Lamps

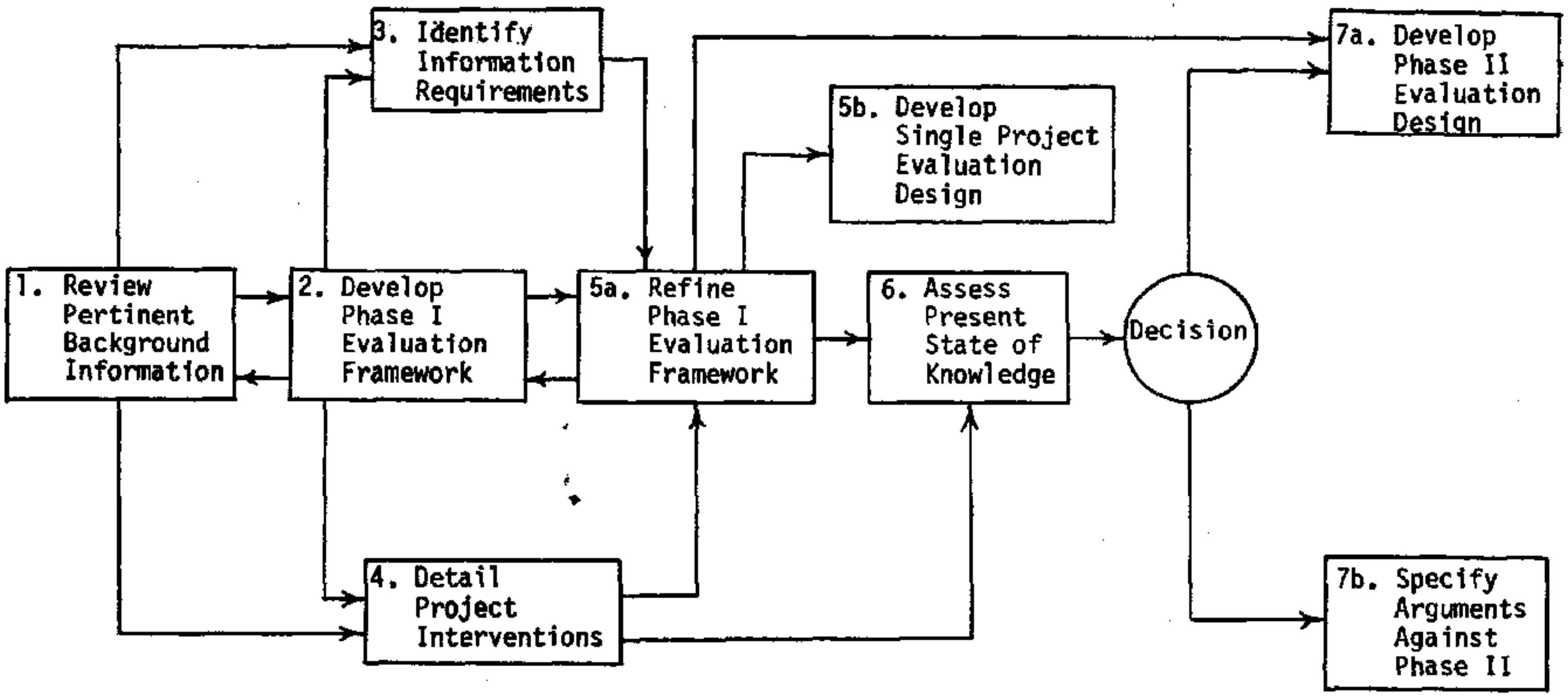
Date	Place	Light Source/Lamp
1558	Paris, France	Pitch-burning lanterns, followed by candle lanterns
1690	Boston, Massachusetts	Fire baskets
1807	London, England	Gaslights
1879	Cleveland, Ohio	Brush arc lamps
1905	Los Angeles, California	Incandescent
1935	Philadelphia, Pennsylvania	Mercury vapor
1937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

(b) Street Lighting Innovations

Sources: [6, 7]

Exhibit 3

Phase I Study Approach



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 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.

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 — 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 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.

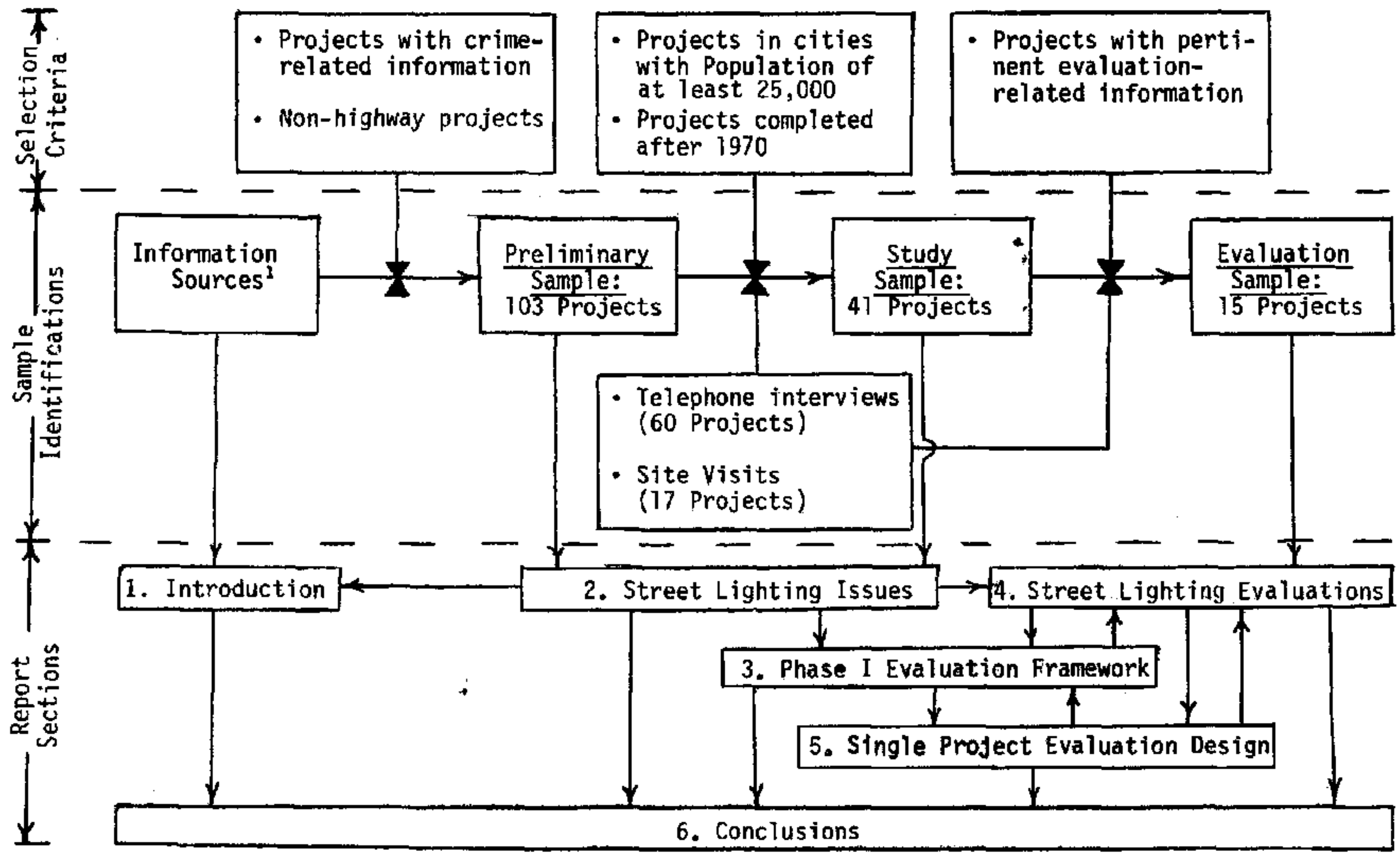
Exhibit 4 also contains a list of information sources. In addition to these sources, telephone interviews were conducted of 60 projects and site visits were made to 17 projects. The projects which were interviewed and/or visited are indicated in Exhibit 5, which identifies all the street lighting projects 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, or there was a project but the wrong city was indicated, or the officials interviewed could only recall the most recent^proje*ct in their city, or no appropriate city officials could be contacted following repeated attempts. 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 4. 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.

Exhibit 4

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.

Exhibit 5

Street Lighting Projects: Preliminar y Sample

City	1970 Population	Project Dates [1]	Phone Survey		Site Visit		Study Sample	
			No	Yes	No	Yes	No	Yes
1. Arlington, MA	53,534	1966-1971		x	x			x
2. Asbury Park, NJ	16,533	1971-1974	x		x		x	
3. Asheviile, NC	57,681	1973		x	x			x
4. Atlanta. <A	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. Benkeiman, 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. Cinclnatti, OH	452,524	1970-1977		x	x			x
19. Cleveland, OH	750,879	1973-1975		x		x		x
20. Oad« 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, HI	193,317	1956	x		x		x	
29. Foster City, CA	9,327	not available	x		x		x	
30. Fort Wayne, IN	17B.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. Gastonii, NC	47,142	1971-1973		x	x			x
34. Greendale, UI	15,089	before 1971	x		X		x	
35. Gulfport, MS	40,791	not avaiiablf	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. M0	507,330	1971-1972		x	x			x

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

Exhibit 5
(page 2 of 3)

City	1970 Population	Project Dates[1]	Phone Survey No	Phone Survey Yes	Site Visit No	Site Visit Yes	Study Sample No	Study Sample Yes
41. Kinston, NC	22,309	1972-1973	x		x		x	
42. Knoxville, TN	174,587	1974		x	x		x	
43. Manchester, NK	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	4 334,859	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, MI	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 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. Ralefgh, 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. Sal ley, 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, HO	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. Make 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, HA	39,307	1966-1971		X	X			X
103. Wichita Falls, TX	96,265	1975-1976		X	X			X

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.

As noted in the Preface, this Summary Report can be regarded as an abridged version of the Final Report. However, the Final Report also includes three appendices which are not summarized herein. 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.

Throughout this report the reader will note that frequent references are made to the Kansas City street lighting study [19], 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 to 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 the planner who is interested in evaluating a street lighting project should, of course, peruse the entire report, as well as the Final 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 6 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 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, legal, and environmental --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.

Exhibit 6

Street Lighting Projects: Study Sample

City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[1]	Target Area(s)	Project Cost ($1,000)*	Light Source(s): Wattage	Light Source(s): Type[5]	Light Source(s): Number	Crime-Related Information Sources: Planning Report*	Crime-Related Information Sources: Evaluation Report[7]	Crime-Related Information Sources: Other[8]
1. Arlington, HA	52,881	not available (n.a.)	1973-1974	schools, parks	n.a.	400U 400-1000W	HPS HV	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 HV	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	HV	75	X		X

'U.S. Bureau of the Census estimates for 1973.

*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.

'Calendar years during which planning and Installation activities were supposed to have taken place.

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

SFL: fluorescent; HPS: high-pressure sodium; LP5: low-pressure sodium; HH: metal halide; HV: mercury vapor

'Includes grant applications.

'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.

"Includes telephone interviews, site visits, annual reports, and pertinent journal articles.

Exhibit 6

(page 2 of 4)

City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[3]	Target Area(s)	Project Cost ($1,000)*	Light Source(s) Wattage	Type[5]	Number	Crime-Related Information Sources Planning Report*	Evaluation Report[7]	Other*
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	260-400W	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**	**400M**	**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.	400U 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	8,560	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 6

(page 3 of 4)

	City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[5]	Target Area(s)	Project Cost ($1,000)-	Light Source(s)			Crime-Related Information Sources		
							Wattage	TvDe[5]	Number	Planning Report[6]	Evaluation Report[7]	Other[1]
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- 250H	HV	762	x	x	x
24.	New Orleans, LA	573,479	6,138	1973-1975	residential	7.0	400M	HV	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	HV	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- 400M	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, HA	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	HV	330		x	x
33.	Portland, OR	375,948	9,673	1975-1976	residential, commercial	447.8	250W 175- 400W	HPS HV	152 287	x		x
34.	Richmond, VA	238,087	6,418	1972-1973	residential, commerci a1	276.0	25 OH 175- 40QW	HPS HV	404 457		x	x
35.	Salem, OR	79,247	6,240	1973	central business	22.0/year	400W	HPS	224			x

Exhibit 6

(page 4 of 4)

City	1973 Population[1]	1973 Crime Index Rate[2]	Project Dates[3]	Target Area(s)	Project Cost ($1,000)*	Light Source(s)			Crime-Related Information Sources		
						Wattage	Type[5]	Number	Planning Report[1]	Evaluation Report[7]	Other'
36. Savannah, GA	105,768	7,142	1970-1974	residential, commercial	364.5/year	250- 400M 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	HV	277		X	X
39. Washington, DC	734,801	6,946	1970 ,	residential, commercial	365.0	250- 400W	HPS	n.a.		X	X
40. Hatertown, MA	37,436	3,318	1966-1971*	city-wide	144.0/year	100- 400W	HV	2,079			X
41. Wichita Falls, TX	95,501	4,529	1975-1976	residential, commercial	109.5	250- 400W	HPS	600	X		X

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 7, the involvement of each participant can occur at different stages in the development of the project. In practice, the city agency with primary responsibility for providing street lighting services usually shares this responsibility with a privately- or publicly-owned utility company. An analysis of the Study Sample projects indicates a tendency for *large* cities to own and maintain their systems, and for *smaller* cities to rely on a regional utility company 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 in turn 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

Exhibit 7

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 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 the Final 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 evaiuator 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 evaiuator. The quality—accuracy, completeness and machine readability—of the data also varies from agency to agency and project to project. Inasmuch as the project evaiuator 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.

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 8. 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.

Exhibit 8

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 £tate Taxes • Special Tax on Income or Luxuries • Investment of Municipal Power Company Profit
Private	• Civic Organizations • Businesses and Merchants' Organizations • Private Citizens

The Law Enforcement Assistance Administration (LEAA) has funded lighting projects 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.

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

---

* 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.

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 *yery* 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.

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 [8]. Methods for coping with regression artifacts are considered in Section 5.2.

Evaluation Efforts Are Brief and Inadequate

Most evaluative statements must, be 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 evalutation 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, what is required for the funding sources is to accept unexpected time delays and budget overruns 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.

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 [9]. 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 1'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^

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, the performance specifications* of the Study Sample projects generally meet or exceed the

---

* 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.

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 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. In fact, recent experiments suggest that horizontal roadway illumination is a good predictor neither of visibility nor of traffic safety [10,11]. Horizontal illumination has been popular primarily because it is easy both to design for and to measure.

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. 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. 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.

Despite the innovative steps taken by industry, a mechanism is required for aggregating and focusing 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 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 enviromental 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.

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 Resigns, 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; 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 [12, 13] 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 [14, 15] 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). The calculation of total annual cost, on the other hand, 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, 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-oycle* 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

---

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

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* [16].

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 thpre any concurrent, possibly energy-related, changes in such activities as police patrol? And are there any other energy-related changes in overall crime patterns?

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. Additionally, the locations of street lighting reductions have mostly been in such places as freeways, where thfc incidence of crime is not prevalent. 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.

---

* 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.

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. 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.

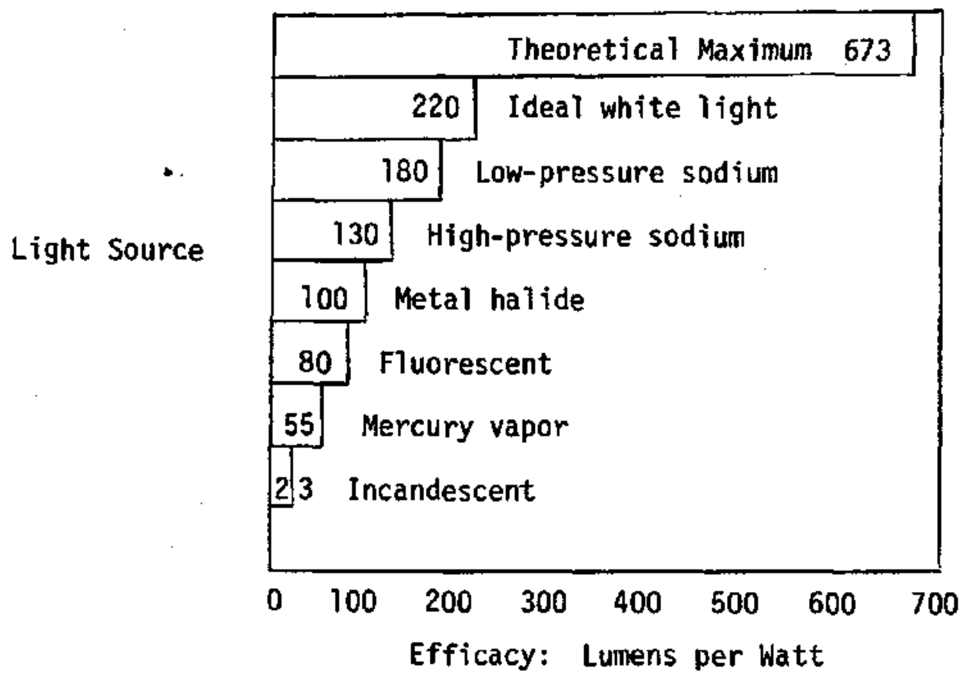
In summary, although it may be possible in the future to identify localities where crime trends during a period of reduced street lighting can be observed retrospectively in a natural experimentation sense, such an evaluation would have to take into account the duration and location of the experiment, 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 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, which, as shown in Exhibit 9, produces more lumens per watt than either mercury vapor or incandescent lamps, which are the two most widely used street lamps in the U.S. today. 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. 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. What is needed, is a total ay stems approach to the design of street lighting systems that are at once energy- and cost-efficient.

Exhibit 9

Relative Efficacies of Light Sources



Source: [17]

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.

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. 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 [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. Foodr, Inc. 311 N.E. 2d 745 (111, App. 1974)]. Testimony in the trial of this case 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 [18, 19] which concluded that street lighting improvements can reduce commercial burglaries and assaults. This situation underlines the need for accuracy and methodological rigor when reporting on the crime prevention effects of street lights.

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 [20, 21]. 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. 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.

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 [22]. 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.

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 a 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 10, an understanding of both the evaluation issues--see the discussion in Section 3.1—and the evaluation guidelines—see, for example references [23, 24]—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 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 10. In sum, Exhibit 10 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 10, 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 11 to be a part of the multi-project evaluation framework.

Exhibit 11 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 10

Evaluation Process

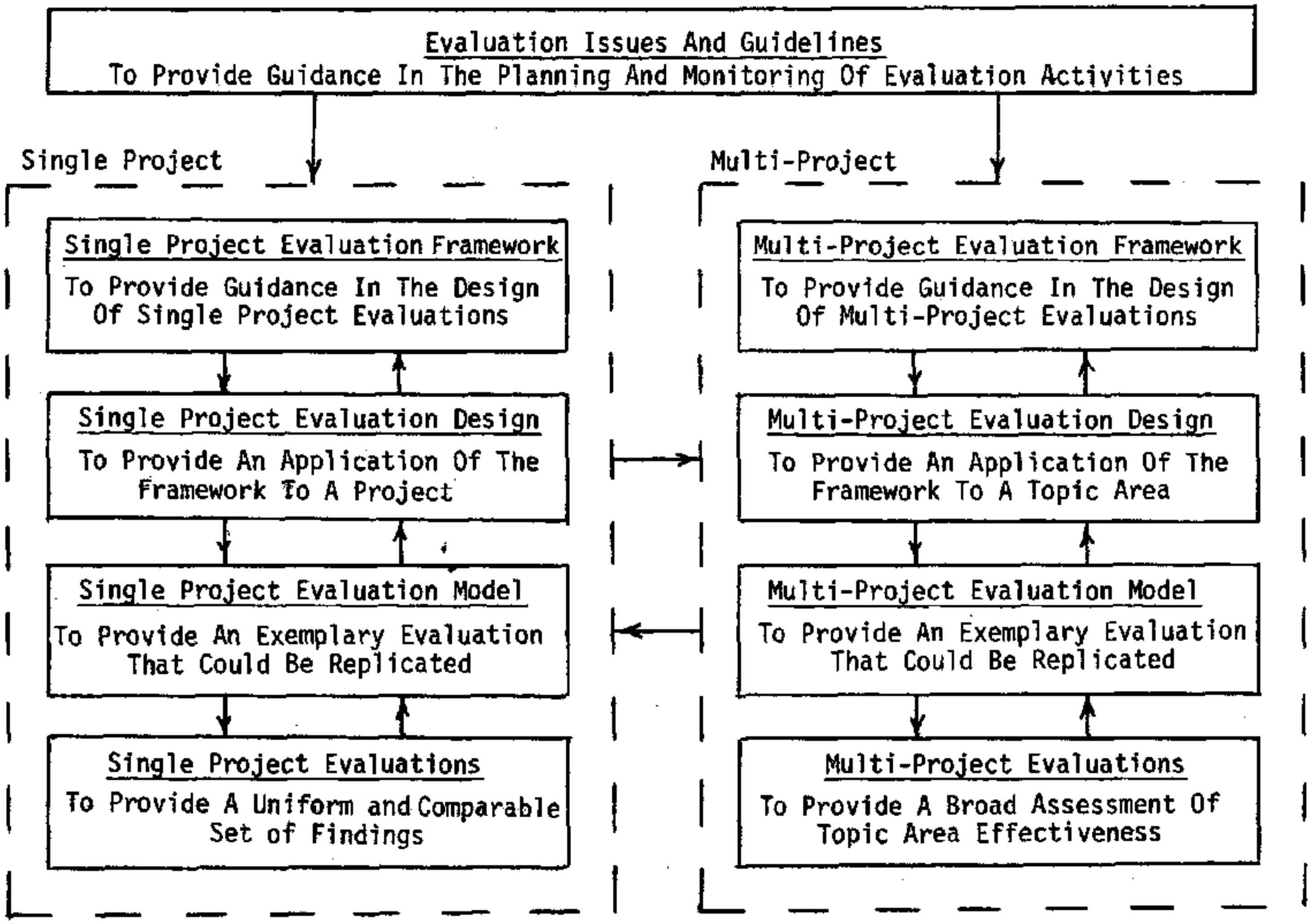


Exhibit 11

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*?

(Evaluation Requirements → Evaluation Components → Evaluation Issues)

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 11 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 of the Final Report 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 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 [25, 26].

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.

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.

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 [27] 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 [28].

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 LO 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, every combination of three occur in a different target area, and so forth. Thus, if there are *I* interventions, then a total of (2^-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 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 10--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 11; 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 10, 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 11, 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, 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 by 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 11, 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 EVALUATIONS

There has been a proliferation of articles and reports claiming that street lighting reduces 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 [29] 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 [30] 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 [31], and again later in a 1970 article [32], 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 [33].

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" [34, 35, 36], 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 [37].

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 [38] and the President's Commission on Law Enforcement and Administration of Justice [39], have already been cited in Section 1.

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 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 12. 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 15 and discussed in Section 5. More specifically, Section 4.1 describes and highlights key aspects of the projects' research designs; Section 4.2 identifies 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 13, 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 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

Exhibit 12

Street Lighting Projects: Evaluation Sample

City	Project Dates[1]	Funding Source[2]	Target Area(s)		Light Source Type[3]	Evaluator[4]	Crime-Related Objectives	Impact Measures
			Land Use	Size				
1. Atlanta, GA	1973-1974	LEAA, Local	Central Business	14 blocks	HPS	Impact Program	• Reduce night Part I crimes, each by 5-15X within one year	Crime
2. Baltimore, MD	1973-1974	LEAA, Local	Not Available (n.a.)	n.a.	HPS	CJCC	• Not stated	Attitudes, Behavior, Crime
3. Chicago, IL	1974-1975	Local	Citywide	3000 miles	HPS	Police Department	• Reduce dtywide crime	Crime
4. Denver, CO	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 25-50X	Attitudes, Crime
5. Harrisburg, PA	1975-1976	LEAA, Local	Residential, Commercial	30 blocks	HPS	Police Department	• Reduce citizens' fear of crime • Reduce robbery, assault, burglary, auto theft, each by 5-202	Attitudes, Behavior, Crime
6. Kansas City, HO	1971-1972	Local	Central Business Residential, Commercial	500 blocks	HPS, HV	Consultant	• Reduce crime	Crime
7. Miami, FL	1972-1977	Local	Citywide	34 square miles	HP 5	Public Works Department	• Not stated	Crime
8. Milwaukee, WI	1972	LEAA, Local	Residential	3.5 miles	HPS	CJCC	• Reduce crime • Increase police capability to detect crime	Attitudes, Behavior, Crime
9. Newark, NJ	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: lowi-pressure sodium; MH: metal halide; MV: mercury vapor.

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

Exhibit 12

(page 2 of 2)

City	Project Dates[1]	Funding Source	Target Area(s)		Light Source Type[3]	Evaluator"	Crime-Related Objectives *	Impact Measures
			Land Use	STze				
10. New Orleans, LA	1973-1975	LEAA, Local	Residential	170 blocks	MV	CJCC	• Reduce night assault, burglary and auto theft	Crime
11. Norfolk, VA	1972-1974	HUD	Residential	11.5 square miles	MV	Consultant	• Promote sense of security • Invite night street use	Attitudes, Behavior
12. Portland, OR	1972-1973	LEAA, Local	Residential	315 blocks	MV	SPA, Consultant	- Reduce stranger-to-stranger street crimes	Attitudes, Crime
13. Richmond, VA	1972-1973	LEAA, Local	Residential, Commercial	n.a.	HPS, HV	Consultant	• Reduce burglary	Crime
14. Tucson, AZ	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	1970	U.S. Congress	Residential Commercial	113 blocks	HPS	Traffic Engineering Department	• Reduce crime • Return the streets to the people	Crime

en
o

Exhibit 13

Evaluation Sample: Researc h Designs

City	Test Hypotheses	Randomization/ Control Scheme	Measures Framework: Input	Process	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; x^2 test Before/after, target/control area comparisons; \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 13

(page 2 of 4)

CUv	test Hypotheses	Randomization/ Control Scheme	Heasures Framework: Input	Heasures Framework: Process	Heasures Framework: Impact	Measurement Methods	Analytic Techniques
Kansas City, MO	• Increased street light-Ing reduces crime • Increased street light-Ing reduces night street crime: In relit blocks more than in non-relit blocks; to different degrees 1n residential and commercial blocks; and to different degrees for residential and commerical burglary targets • Increased street light-Ing displaces some night street crime	• Target and control areas: stratified samples of relit, non-rel1t 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; x^J 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, HI	• Increased street lighting reduces night crime * Increased street light-Ing 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 s 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 light-Ing 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

en ro

Exhibit 13

(page 3 of 4)

City	Test Hypotheses	Randomization/ Control Scheme	Measures Framework: Input	Measures Framework: Process	Measures Framework: Impact	Measurement Methods	Analytic Techniques
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 * SIX) • 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 13

City	Test Hypotheses	Randomization/ Control Scheme	Measures Framework			Measurement Methods	Analytic Techniques
			Input	Process	Impact		
Richmond, VA	• Hot stated	• Not stated	• Not well defined except for system design and target area	• Not well defined except for design verifica- tion, In- stallation cost and concurrent law en- forcement 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 com- pletion 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 en- forcement, 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 In- stallation (to- tal sample size - "several hund- red"; response rate not stated)	• Before/after, tar- get/control area comparisons of survey results • Time series analy- sis of crime data (entire street lighting area)
Washington. DC	• Increased street light- Ing 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

hypotheses listed in Exhibit 13 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. On the other hand, the New Orleans project analyzes the *target crimes* involved in the test hypotheses. The project observes that, although these target crimes (i.e., business burglary, assault and auto theft) are the ones most likely to be reduced, none is a "pure" nighttime crime, so that an explicit hypothesis would be limi*ed 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. Similar difficulties can be 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 15 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 dtscussed 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?"

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. 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—Newark—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 behavior 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.

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 identified 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 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 walk or drive through different combinations of 19 target and control area environments. 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*

---

* 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 demogranh-ir characteristics.

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. 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.

<u>Regression Analysis</u>

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.

Time Series Analysis

Time series analysis is reported in the New Orleans and Tucson evaluations. Onl y the former describes its time series techniques 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. Th e 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 METHODOLOGICA L 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. Accordin g to Suchman, evaluation is [40]:

> 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 tHbt 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. Ther e 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. All of these problems are obvious from the discussion in Section 4.1.

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, *obsowes* both before/after and target/control area comparisons. Moreover, it is almost impossible to perform inter-project comparisons, since one project's relit *area*eould be* equivalent to another project's non-relit area.

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 some of the 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 13, 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 an illustration, an analysis in the Kansas City evaluation is critically reviewed. In this evaluation, 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 judgment 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 14 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 14

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, MO	• 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% 1n one year • Reported residential burglary increased (time of day not stated)	• Not stated	. RD, EH. 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, EH. 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)	. EH, 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 thei^ performance*[1]	• No impact on reported night robbery, assault. burglary or auto theft	• Not stated	. RD. EM. IM. AT

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

[3]R0: research design 1s lacking; EH: explanatory measures art lacking; IH: Impact measures are lacking; AT: analytic techniques are misused. These problems are discussed in Section 4.3.

Exhibit 14

(page 2 of 3)

City	Reported Impacts* Attributed to Street Lighting: Attitude	Behavior	Crime	Statistical Significance of Results: 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 V* to ⅓ of "prevented" night street robberies were displaced to adjacent nonrelit blocks	- Significant at .05 * level • Not significant at .10 level . Not stated	• **RO, EH, AT**
Miami. FL	• Not addressed	• Not addressed	• Reported night crimes against person decreased twice as much **In target area as in** entire city, 1n one year • No Impact on reported night crimes against property	• Not stated • Not stated	• RO, EH, 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)	- RO, EH, IH, 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, EH, IH, 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	• EH, AT

Exhibit 14
(page 3 of 3)

City	Reported Impacts[1] Attributed to Street Lighting			Statistical Significance of Results	
	Attitude	8ehav1or	Crime	Reported Significance	Methodological Problems[2]
Norfolk, VA	• Street lighting systems with relatively higher uniformity, lower Il-lumination, 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 "insuffi-cient lighting"	• Not addressed	• Not explicitly stated, but Interpretation of multiple regression results Implies sta-tistical significance	. IH
Portland, OR	• ***25%* of target area** residents were aware of Increased street lighting • No Impact on residents' feelings of safety • Citywide, the associa-tion between percep-tion of and actual street lighting quan-tity was "not very strong"	• **Not addressed**	• No Impact on reported night robbery, assault or burglary	' Attitude: not expli-citly stated* but analysis of associa-tion among survey re-sponses Implies sta-tistical 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 "sub-stantially safer", and reported "less fear" walking through alleys at night	• Not addressed	• No impact on total re-ported Part I crime	• **Not stated**	. **EM. IM, AT**
Washington, D.C.	• Not addressed	• Not addressed	• Reported night robbery, residential burglary, auto theft and van-dalism decreased by ***65%*, 44%, 561, 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:

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

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

---

* However, only 25 percent of the Portland respondents indicated that they were aware of the existence of new lights.

individual's sense of security.* While the Norfolk evaluation appears to be methodologically sound, it is unique and should be replicated elsewhere.

BEHAVIOR IMPACTS

Tabulated survey data on reported changes in behavior reveal 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

---

* 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.

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 result?.

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

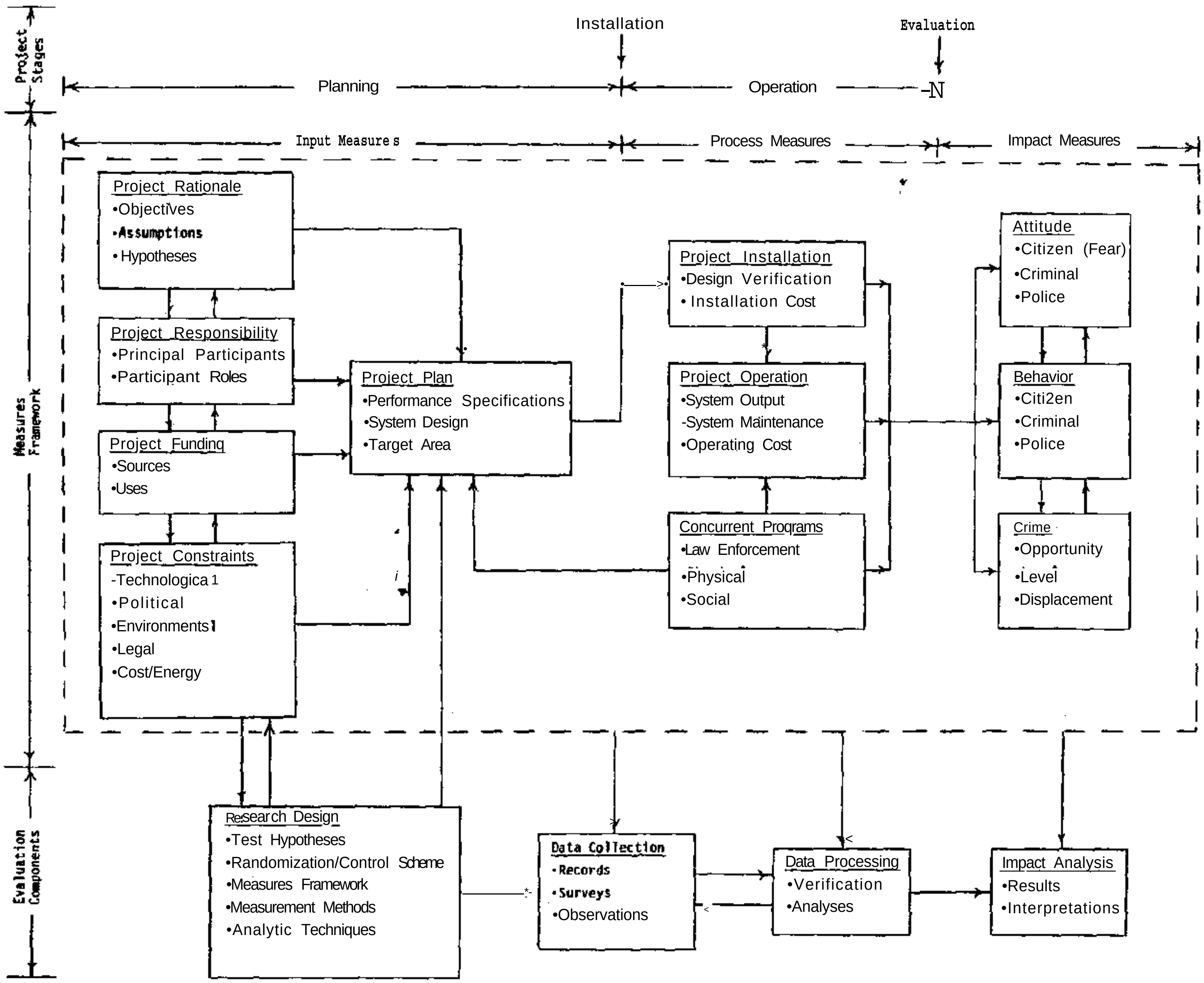
The conduct of an evaluation frequently presents problems both to the evaluator and the staff of the project being evaluated, resulting in evaluation findings that may be limited in both validity and relevance. One problem is the apprehension on the part of the project staff on being "evaluated." The 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 judgment 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 10 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 15. It is seen that the evaluation requirements of Exhibit 11 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 15 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

Exhibit 15

Single Project Evaluation Design



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 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 16, 17 and 18, 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 16 and 17 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.

The relation between the measures framework and test hypotheses is illustrated in Exhibit 19, 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 19 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 19 because its measures are assumed by some programs (i.e., the Crime Prevention Through Environmental Design—CPTED—program) to have a supportive or *synergistie* effect,

Exhibit 16

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 coet* 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 factor* fe.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 16
(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.
		• Number and location of street lights. [Determine these measures for both the old and the new system.]
	• System Design	• 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 *differenoes.'}*
		• 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 17

Measures Framework: Proces s 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-reeommended 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-patroi *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 18

Measures Framework: Impac t 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, recijgnize, 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.

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

Exhibit 18

(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 *1* 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.]

Exhibit 19

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]									

[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.

along with light output, on the impact measures. However, as indicated in Exhibit 19, the synergistic test hypotheses have not yet been tested. In fact, the large number of empty cells in the Exhibit 19 matrix highlights the *dearth* 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 15, but, as a group, with the evaluation's research design. Not only do these input considerations establish a set of constraints on 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 [41]. 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 wHAesses 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 15, 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.

Finally, 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.

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

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, thfire is no universal formula for accomplishing this target-control area equivalence.

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.

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 16, 17 and 18, 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 16, 17 and 18 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 $ne 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.

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 moredetail 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 tombining irrelevant assumptions with the street lighting test hypotheses.

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 focus on the effects of street lighting and exhaust 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 then 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 hypothesis, 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 detailed numerical example is given in the Final Report as an illustration of the ratio method.

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 detailed and systematic approach should be taken.

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.

---

* 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.

Testing of Ratios

The actual test of the impact of street lighting is governed by the ratios selected. Once selected, the ratios can be tested using a chi-square test. 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.

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 [42]. 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 i^ a *s*ocio-economic measure, A is an attitude measure, e is a random fluctuation with some standard deviation a, and a, b, c, d and a 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 *oomplete* 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. In practice, however, a significant amount of *systematic* variation may be due to influences other than the identified explanatory measure, in which case the assumption that the error term in the time series analysis is random is not valid. A recently reported method by Box and Tiao [43] for addressing this difficulty entails modelling both the error term 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 [44]. A conventional analysis assuming a random error term was performed first, indicating an apparent street lighting impact. However, further inspection revealed that the randomness assumption was not valid for the error term. 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.*

---

*"Stochastic Modelling and Analysis of Crime," LEA A Grant No. 75 NI-99-0091, awarded to Georgia University of Technology, (Dr. Stuart Deutsch, Principal Investigator).

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 step-wise function of light; that is, the level of fear remains relatively constant between certain ranges of light and changes significantly at other ranges.

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 20 summarizes the various issues, gaps and recommendations.

A quick review of Exhibit 20 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.

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

---

* 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.

Exhibit 20

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 sh*uld (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 20
(page 2 of 2)

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 1n 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-effeetiveness 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 nake it difficult to acquire data that are consistent and uniform. A *model* evaluation would allow projects to collect and maintain comparable data.

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 [45, 46, 47] can guide the identification of a research agenda for a study of light and personal security. As discussed in Appendix B of the Final Report, 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 Vecommended 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" [48] 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.

REFERENCES

1. President's Commission on Law Enforcement and Administration of Justice, "Task Force Report: Science and Technology," Washington, D.C., U.S. Government Printing Office, 1967, p. 51.

2. National Advisory Commission on Criminal Justice Standards and Goals, "Community Crime Prevention—Report of the National Advisory Commission on Criminal Justice Standards and Goals," prepared for the Law Enforcement Assistance Administration, Washington, D.C., 1973, p. 199.

3. Sarah Carey, "Law and Disorder," prepared for the Center for National Security Studies, 1976.

4. Twentieth Century Fund, "Law Enforcement: The Federal Role," Task Force Report, 1976.

5. Carl Kellum, George Harmansky, Elizabeth Landan, and John Denis West, "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.

6. Charles W. Beardsley, "Let There Be Light, But Just Enough," IEEE Spectrum, December, 1975, p. 28.

7. Edison Electric Institute, Street and Highway Lighting Committee, "Street Lighting Manual," 2nd Ed., 1969.

8. Donald T. Campbell and Julian C. Stanley, "Experimental and Quasi-Experimental Designs for Research," Rand McNally & Co., Chicago, 1966. Reprinted from "Handbook of Research on Teaching," N.L. Gage, Ed., Rand McNally, 1963.

9. Illuminating Engineering Society of North America, "American National Standard Practice for Roadway Lighting," Journal of the Illuminating Engineering Society, July, 1972.

10. V. Gallagher, B. Koth, and M. Freedman, "The Specification of Street Lighting Needs." Report No. FHWA-RD-76-17, prepared by the Franklin Institute Research Laboratories for the Federal Highway Administration, November, 1975.

11. Michael S. Janoff, Bruce W. Koth, William D. McCunney, Mark Freedman, and Michael J. Berkovitz, "Effectiveness of Highway Arterial Lighting, Phase I—Interim Report (Draft)," prepared by the Franklin Institute Research Laboratories for the Federal Highway Administration, September, 1976.

12. Op . Cit. [10].

13. Neilo n 0. Rowa n and Patrick T. McCoy, "An Interim Report on a Study of Roadway Lighting Systems." Research Report 75-1, Texas Transportation Institute, Texas A&M University, Texas, August, 1966.

14. Arn o Cassel and Douglas Medville, "Economic Study of Roadway Lighting," National Cooperative Highway Research Program (NCHRP) Report No. 20;'Natlonal Research Council, National Academy of Sciences, 1966.

15. Op . Cit. [11].

16. Genera l Electri c Company Lighting Systems Business Department, Hendersonville, North Carolina, "Light Concepts for Conservation," Fact Sheet No. 100A.

17. Op . Cit. [6].

18. Charlott e Jones, "The Impact of Street Lighting on Crime and Traffic," Education and Public Welfare Division, Library of Congress, Legislative Reference Service, August 31, 1970.

19. R . Wright, M. Heilweil, P. Pelletier and K. Dickinson, "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.

20. "Outdoo r Lighting Effects on Trees—Ecology, Energy, Safety and Security," Electrical South, May, 1974.

21. Jac k H. Stark, "High Intensity Lighting and Its Effects on Trees and Plants," Miami, Florida Department of Public Works, July 22, 1975.

22. J.M . Tien, T.A. Reppetto, et al., "Elements of CPTED: A Preliminary Report," Urban Systems Research and Engineering, Inc., Cambridge, Massachusetts, 1975.

23. Joh n D. Waller, Dona MacNeil, John W. Scanlon, Francine L. Tolson, and Joseph S. Wholey, "Monitoring for Criminal Justice Planning Agencies," National Institute of Law Enforcement and Criminal Justice, March, 1975.

24. Donald R. Weidman, John D. Waller, Dona MacNeil, Francine L. Tolson, and Joseph S. Wholey, "Intensive Evaluation for Criminal Justice Planning Agencies," National Institute of Law Enforcement and Criminal Justice, July, 1975.

25. Richard H. Blackwell, "Development of Procedures and Instruments for Visual Task Evaluation," Illuminating Engineering, April, 1970, p. 267.

26. Op. Cit. [11].

27. Op. Cit. [22], Section 4.2.

28. Thomas A. Reppetto, Residential Crime, Cambridge, Massachusetts, Ballinger Publishing Company, 1974.

29. Don Murray, "How Bright Lights Reduce Crime," Coronet Magazine, February, 1960.

30. Don Callender, "Light, A Weapon in War on Accidents and Crimes," American Motorists, March, 1962.

31. J. Edgar Hoover, "The Lighted Way," General Federal Clubwoman Magazine, February, 1963.

32. J. Edgar Hoover, "Out of the Darkness," Street and Highway Lighting, Vol. 20, No. 4, 1970.

33. Op. Cit. [5].

34. Beverly L. Bennet, "The Impact of Street Lighting on Crime and Traffic Accidents," Education and Public Welfare Division, U.S. Library of Congress, Washington, D.C., May 7, 1976.*

35. Nancy Berla, "The Impact of Street Lighting on Crime and Traffic Accidents," Education and Public Welfare Division, Library of Congress Legislative Reference Service, October 4, 1965.

36. Op. Cit. [18].

37. "Correlation between Street Lighting and Crime," prepared for Rep. Charles P. Farnsley by the Education and Public Welfare Division, U.S. Library of Congress, Congressional Record (House), October 12, 1965, p. 25855.

38. Op. Cit. [2].

39. Op. Cit. [1].

40. Edward A. Suchman, "Evaluative Research," Russell Sage Foundation: New York, 1967, p. 28.

41. Shlomo Angel, "Discouraging Crime through City Planning," W.P. Number 75, Institute of Urban and Regional Development, University of California, Berkeley, February, 1968,

42. Op. Cit. [11].

43. G.E.P. Box and G.C. Tiao, "Intervention Analysis with Applications to Economic and Environmental Problems," Journal of the American Statistical Association, March, 1975, pp. 70-74.

44. Philip B. Krause, "The Impact of High Intensity Street Lighting on Nighttime Business Burglary," Human Factors, 19(3), June, 1977, pp. 235-239.

45. Op. Cit. [25].

46. Op. Cit. [10].

47. Op. Cit. [11].

48. Op. Cit. [43].

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979-281-380/1551