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ABSTRACT

This interim report informs the eventual user of the direction of the long-term program; specific criteria are not provided. Five current guidelines in lighting practice were disavowed as follows--(1) that low levels of illumination cause organic harm to the eyes, (2) that the footcandle is the best criterion for determining the proper illumination of a space, (3) that increasing the level of light intensity is the only way to improve visual performance, (4) that rooms with uniform task distribution require uniform lighting, and (5) that uniform lighting is desirable even in rooms with non-uniform task distribution. Plans for follow-up studies and the final report form were discussed. Appendix I lists conference participants. Appendix II presents a design checklist guided by an overall building concept. (KK)

INTERIM REPORT

PERFORMANCE CRITERIA FOR THE LUMINOUS ENVIRONMENT

A Research Project being conducted for the State University Construction Fund, State of New York, by the Massachusetts Institute of Technology.

STATE UNIVERSITY CONSTRUCTION FUND
194 WASHINGTON AVENUE
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FOREWORD

A program to develop a series of documents on performance criteria for the planning, design and construction of new university buildings is being conducted by the State University Construction Fund. Each document will cover a specific component of a building project: structure, acoustics, finishes, lighting, etc. The criteria will be presented in generic terms, compatible with the state of the art, and in language comprehensible to all parties to the planning/construction process: owner, educator, architect, consultant, contractor, and manufacturer. Currently, environmental research is being carried on for the Fund in acoustics, finishes, HVAC, and lighting. This report summarizes the work to date on the lighting project. As an Interim Report the intent is not to provide specific criteria, but rather to inform the eventual user of the direction we have taken and ask for comment.

OVERVIEW OF THE LIGHTING RESEARCH PROJECT

Why the Project?

Most research in lighting in the past has been concentrated on illumination levels for carefully defined and restricted tasks under controlled conditions. Such research was necessary to provide a starting point for design; it was not meant to provide hard and fast criteria for the designer to follow. Unfortunately, the illumination levels presented in these studies have frequently been incorporated uncritically in lighting codes and the codes have been used by designers in specific building projects where the actual environments differed widely from the research environments. This practice often has resulted in less-than-satisfactory illumination because the importance of the environmental factors usually outweighs the importance of the illumination levels *per se*.

During 1966, the Fund commissioned the School of Architecture at Pratt Institute to study existing work that had been done in lighting research during the past fifty years and to evaluate lighting recommendations stemming from it. These studies showed that it was impossible to draw a consensus that would be valid in terms of a general approach to lighting design. The Pratt report revealed such great disparities and conflicts that trying to draw averages would be meaningless. The Fund, therefore, decided to undertake a project which would try to reconcile field observations with research findings by drawing together not only specialists in lighting research but representatives from the behavioral sciences, medicine, education, and architectural design, to seek out areas of agreement, and to probe into areas which remain matters of conjecture.

How the Project Was Initiated

Late in 1966, the Fund commissioned the Massachusetts Institute of Technology as consultant for the research project. Dr. Albert G. H. Dietz, Professor of Building Engineering, was selected to head the project group; Mr. William M. C. Lam, of William M. C. Lam & Associates, to serve as principal consultant to M.I.T. Others appointed to the staff were Professors E. Neal Hartley and Robert Rathbone and Mr. Robert Pelletier. Director of Research and Development for the State University Construction Fund is Richard G. Jacques. Research Associate for the Fund is Mr. William Sawyer.

Specific plans for conducting the project were drawn up at a series of staff meetings in December. Activities were scheduled for completion in four phases:

1. Preparation for a conference on The Luminous Environment
2. Conference
3. Evaluation and reporting
4. Dissemination of research results

At the time of the writing of this report, Phases 1 and 2 have been completed and work has begun on Phase 3.

The major part of this project is financed by a grant from Educational Facilities Laboratories, Inc., which was established by the Ford Foundation in 1958 to help schools and colleges solve their physical problems by encouraging research, experimentation, and the dissemination of knowledge regarding education facilities.

A two-day conference on The Luminous Environment was held at Skidmore College, Saratoga Springs, New York, July 6 and 7, 1967. The reason for this conference was to bring together for discussion, debate, and exchange of ideas representatives from education and architecture, and specialists from medicine, the behavioral sciences, and illumination. The objective was to obtain specific suggestions for performance criteria that would serve the needs of the State University Construction Fund program.

Preparation

The conference required much planning and preparation; establishing an agenda, attracting key participants (see Appendix I for names and backgrounds), and compiling a "position" paper on the luminous environment that would serve as a guide for the discussions. Preparing the paper involved interviewing researchers both in this country and Great Britain, reviewing current literature, drafting survey methods of evaluating existing practice, outlining suggested types of performance criteria, defining terms, suggesting points for discussion, providing specimen check lists, and outlining a design program. Advance copies of the paper were distributed to those attending the conference. The bulk of preparation was done by Mr. Lam.

Proceedings of the Conference

The general proceedings of the conference followed a well-defined plan. The first day was devoted primarily to comments by the specialists; the second day, to comments by the generalists -- the architects and educators. No formal papers were presented; the discussions were informal -- moderately controlled so that everyone had freedom of expression.

The guidelines for the discussions were the position paper and a series of slides presented by Mr. Lam to illustrate various elements of the luminous environment. Since everyone had received a copy of the paper in advance and many had already submitted written comments, an item-by-item, paragraph-by-paragraph coverage was unnecessary. A general coverage by chapters, however, was followed.

To help those who must evaluate the deliberations and write the final report, a stenographic record was kept of all that was said during the formal sessions of the conference. This record has been transcribed into two volumes and is now being used by the MIT project group.

A New Sense of Direction

The Skidmore Conference produced many useful and constructive results. Underlying all the discussions was the recognition of the important role of the total environment in determining effective lighting criteria. Especially noteworthy was the emphasis everyone placed on the humanistic elements of perception, such as proper rendition of color; acquisition of meaningful information; avoidance of discomfort, distraction and gloom; and creation of a comfortable, pleasing environment. Noticeably de-emphasized by the participants were the mechanistic factors -- footcandle tables, brightness ratio, scissors curve, etc.

The specialists as well as the generalists agreed that many problems in lighting design can not be met simply by applying a number or even a set of numbers. The designer and the architect often face situations which are not clear-cut, not strictly black or white, and therefore must base many of their final decisions on their own value judgements. The participants further agreed that any set of criteria for lighting design, to be of real value, must offer guidelines upon which these judgements can be firmly based.

Many Current Guidelines Disavowed

In line with the new sense of direction that the conference followed was the refutation of many of the "sacred cows" of current design practice:

1. Low levels of illumination cause organic harm to the eyes.
   This myth was rejected. Medical evidence does not substantiate the claim. Poor illumination causes no more organic harm to the eyes than indistinct sound damages the ears.

2. <u>The footcandle is the best criterion for determining the proper illumination of a space</u>. Agreement was unanimous that this type of standard is inadequate. The conferees recommended that a performance index be developed that would consider quality of lighting as well as quantity.

3. <u>Increasing the level of light intensity is the only way to improve visual performance</u>. Increasing intensity will result in improvement only when all other factors remain constant. Even then, large increments are necessary to produce small degrees of improvement. Quality, not quantity, is the key. A small improvement in the quality of the luminous environment will produce a much greater degree of improvement in performance than will a large increase in intensity.

4. <u>Rooms with uniform task distribution require uniform lighting</u>. Adoption of a single cut-off value for the total area of a room ignores the fact that visibility is often satisfactory over a wide range of illumination. Since value judgements are used in creating criteria, the conferees pointed out that if 70 to 80 per cent of the area meets the required criteria the lighting is likely to be satisfactory.

5. <u>Uniform lighting is desirable even in rooms with non-uniform task distribution</u>. The participants disagreed markedly with this generalization; they proposed instead a moderate level of high-quality room lighting, suitable for most tasks, augmented by local lighting for the performance of unusually difficult or specialized tasks.

Present Analysis Techniques Challenged

The present technique of identifying the most difficult visual task to be performed in a room and then specifying the lighting design based on this task was labeled as ineffective and inefficient. Often the most difficult task is performed only 5 per cent or less of the time the room is being used; to design the total room lighting specifically to meet that five per cent would be unrealistic and costly. Instead, all tasks should be identified at the outset and the percentages of times used should be analyzed. Total room lighting should not be designed for the most difficult task unless it is unquestionably the most predominant task. Additional light can be supplied as needed.

Another technique that came under fire was the American system for determining direct glare discomfort in lighting. The conferees concluded that Dr. Ralph Hopkinson's formula as presented in the British Illuminating Engineering Society (IES) Code offers a better approach. They consequently agreed to recommend its inclusion, in slightly modified form, as part of the performance criteria to be compiled for the SUCF project.

Finally, everyone (including the architects) agreed that in current practice the architect too often does not become sufficiently involved with decisions on lighting design. The consensus of the conference was that the architect has the right general background for this responsibility and that he must become more involved. To aid him in this responsibility, performance criteria must be written in terms meaningful and useful to him.

*Based on brightness of source, apparent size of source, surround brightness, brightness of immediate surround to the source, and the angle between the direction of the source and the direction of viewing.

Subcommittees Formed

Two subcommittees were formed at the end of the first day to meet that evening and report to the conference the following day. One subcommittee, led by Dr. H. Richard Blackwell, was charged with investigating visual performance; the other, led by Mr. William M. C. Lam, with investigating the humanistic or psychological aspects of lighting.

In reporting the deliberations of his subcommittee, Dr. Blackwell proposed that a Visual Performance Index (VPI) should be adopted to replace the footcandle standard. In summary, the VPI would involve three factors: (1) the amount of luminance in a task, (2) the amount of contrast produced by the environment, and (3) the amount of disability glare in the environment. Spaces would be identified as falling into one of three classes according to the type of visual performance involved: those falling into Class I would require minimum illumination. (This information will be developed in detail in the final report).

Following the Blackwell presentation, Mr. Lam reported the discussions of his subcommittee. His main points were:

1. Many psychological (i.e. humanistic) factors are involved in determining the proper luminous environment for a given space or building.
2. Although psychological research has not reached the point where the role of these factors can be proved scientifically, the group believes that they are valid and that they should be incorporated in the performance criteria prepared for the State University Construction Fund.

3. A general numerical weighting should be applied to the psychological factors as well as to the mechanistic or physiological factors. Expressed in terms of percentages, such a comparison will show the importance that the architect or designer should attach to each of the two areas.
4. Information gathered by means of "Design Check Lists" would provide a realistic basis upon which the architect or designer could formulate his judgement values. The performance criteria to be prepared for the SUCF should offer such a list, accompanied by numerous examples of its use. A specimen check list was shown to the conferees by Mr. Lam and they agreed that this type of format should be followed (see Appendix II).

Follow-up Studies

Research will continue during 1968. The first order of business will be to survey the types of tasks and their distribution in representative rooms and buildings in the State University system. This will lead directly to the preparation of appropriate Design Check Lists.

Once the information on tasks is available, the two subcommittees will then have to determine through further research and experimentation the qualitative and quantitative criteria that will best satisfy each situation.

Finally, guidance examples will be drawn up that will illustrate how to apply the criteria to information obtained from the Design Check Lists. Each example will have to be validly demonstrated before being accepted for publication.

Final Report

During the conference, specific suggestions were made concerning the content, organization, style, and format for the final publication on performance criteria requested by the State University Construction Fund. Particular attention was given to the comments by the architects, since they represent an important ultimate user.

All suggestions were reviewed after the conference by the M.I.T. research group and at a subsequent meeting in Albany with representatives of the Fund. The following general outline was adopted:

1. General Principles. The document will begin with a "general principles" section addressed to the non-technical reader. Factors of the "luminous environment" will be presented in simple, qualitative terms.

2. Task Criteria. The second section will discuss task criteria, both in terms of a Visual Performance Index and value judgements. Weightings will be related directly to the factors presented in Section I.

3. Design Program. This section will cover implementation. It will present a design program based on the information in the first two sections. The heart of the program will involve Design Check Lists (to be filled in by the architect or designer, with assistance from the building committee or other planning group). The list will be followed by guidance examples of lighting design in representative university rooms. As much visual material as possible will be used in conjunction with text.

APPENDIX I
CONFERENCE PARTICIPANTS

STATE UNIVERSITY CONSTRUCTION FUND

Richard G. Jacques
Director of Research and Development

William C. Sawyer
Research Associate
Project Coordinator

Rima E. Bostick
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Morton Gassman
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Thomas Davis
Assistant for Facilities Research
Department of Architecture & Facilities

EDUCATIONAL FACILITIES LABORATORIES, INC.

Jonathan King
Vice-President and Treasurer

M. I. T. PROJECT GROUP LEADERS

Dr. Albert G. H. Dietz
Professor of Building Engineering at M.I.T. Director of the Project. Past director of Building Research Institute; past Director of American Society for Testing and Materials; past Chairman Building Research Advisory Board; Materials Advisory Board Committees for Department of Defense.

Robert J. Pelletier
Research Associate, Department of Architecture, M.I.T. Extensive experience in hospital design and research, and other phases of research in design and construction.

Professor Robert Rathbone
Department of Humanities
Project Editor

William M. C. Lam
Lighting Consultant, William M.C. Lam & Associates. Primary consultant to M.I.T. for this project. Extensive experience in coordinating lighting and architecture. Projects have included a broad range: schools, cultural centers, office buildings, hospitals, streets, campuses.

APPENDIX I
CONFERENCE PARTICIPANTS

SPECIALISTS

Dr. H. Richard Blackwell
Director, Institute for Research In Vision, Ohio State University. His findings form the basis of current U.S. lighting criteria.

Dr. Robert M. Boynton
Professor of Psychology, Director of Center for Visual Science at University of Rochester.

John M. Chorlton
Headed the committee responsible for the 1962 American Standard Guide for School Lighting. Chairman of Education Committee, IES; member College Lighting Committee.

Dr. David Cogan
Chief of Ophthalmology, Massachusetts Eye and Ear Infirmary, Boston, Mass. Henry Willard Williams Professor of Ophthalmology, Harvard University.

Dr. James J. Gibson
Professor of Psychology at Cornell. Author of "Perception of the Visual World" and "The Senses Considered as Perceptual Systems."

James W. Griffith
Chairman, Department of Industrial Engineering, Southern Methodist University. Authority of Daylighting; U. S. Delegate to numerous international meetings on the subject. Vice-President, IES.

Dr. R. G. Hopkinson
Professor of Environmental Design and Engineering, University College, London. Studies on glare adopted by IES of Great Britain. Research on lighting formed basis of building regulations issued by Government Education Authorities. Formerly in charge of the lighting work at the Building Research Station, England; Past Pres. IES, Great Britain.

Peter Manning
Founded and directed Pilkington Research Unit at University of Liverpool, a multi-disciplinary team investigating the "total environment" within buildings. Editor of "Office design. a study of environment" and other reports.

Thomas Markus
Professor of Building Science, University of Strathclyde, Glasgow. Studies in use of glass and windows. Research in environmental problems. Established lighting research department at Pilkington Brothers Glass Co. Author of "The Function of Windows-A Reappraisal".

Foster K. Sampson
Consulting engineer in all phases of electrical design, including schools and universities. Member, committee responsible for the 1962 American Standard Guide for School Lighting.

J. M. Waldram
Consulting lighting engineer (England): daylight, street lighting, problems of seeing and visibility, new methods of interior lighting; Past President, IES of Great Britain.

Dr. Brian W. P. Wells
Professor of Psychology, clinical psychologist. Concerned with problems of architectural psychology; member of Pilkington Research Unit.

GENERALISTS

John Hancock Callender
Professor of Design and Construction, Pratt Institute. Director of demonstration project to reduce cost of high-rise and low-income housing.

Ranger Farrell
Architect. Acoustical-lighting consultant to numerous educational construction projects.

George Hutchinson
Architect, partner, Perkins and Will, Chicago. Many projects in the area of higher education: University of Denver, Utica College, Knox College, Concordia Teachers College. Chicago Housing Authority. Federal Housing Administration. Chicago Planning Commission.

Alexander Kouzmanoff
Architect and Professor. Victor Christ-Janer Associates. Currently developing Nassau College for S.U.C.F.

G. Theodore Larson
Professor. Director of School Environments Research Project, University of Michigan. Current study: the effects of environment on the learning process.

Bernard Rubin
Electrical Consulting Engineer. Formerly design engineer for the Hydro-Electric Power Commission of Ontario.

Bernard Spring
Professor. Senior Research Architect and Lecturer at School of Architecture, Princeton University: Technology of Environmental Control. Co-director, AIA Research in Education, Princeton University.

Peter Tirion
Architect. Full-time staff member of the Metropolitan Toronto School Board's Study of Educational Facilities.

SPECIMEN I. DEVELOPMENT OF OVERALL BUILDING CONCEPT

Develop overall lighting concept of building and then check against the individual room check lists for specific conditions.

Type of Building:

Predominant Uses:

Secondary Uses:

Dominant characteristics which should be supported by the lighting design
(number in relative order):

circulation pattern	________
articulation of services	________
articulation of structure	________
articulation of materials - or building organization by color	________
modular flexibility	________
view	________
other (name) ________	________

SPECIMEN 2. INDIVIDUAL ROOM EVALUATION: GENERAL CLASSROOM

Space: General Classroom

Project ________________
Room # ________________

	% by survey	% assumed for project
<u>When is the space used?</u>		
daytime		
nighttime		
What is the space used for:		
a. Two-dimensional horizontal:		
with fixed orientation		
any direction		
reading pencil writing at desks or tablet arms		
reading ink or printed matter		
writing with ink or pencil		
b. Two-dimensional vertical		
chalkboard		
tackboard displays		
c. Three-dimensional		
displays and demonstration:		
throughout space at platform area		
d. Audio-visual		
slides		
overhead projection		
rear projection		
television		
e. Non-visual		
listening		
discussion		

APPENDIX II
DESIGN CHECK LIST

<u>What are the lighting Objectives?</u>

For the tasks:

a. Two-dimensional horizontal
   reading pencil writing: TII (Task Information INDEX) = 1.3*
   reading ink or printed matter: TII = 1.5
   note taking, ink or pencil: TII = 1.0 (0.8 during projection)

b. Two-dimensional vertical
   chalkboard: TII = 1.5 (1.3 during projection)
   Tackboard displays: TII = 1.5

c. Three-dimensional
   average vertical footcandles/horizontal footcandles
   = 1/3 with a minimum* of 1/10

d. Audio-visual
   provide means of light control (window shading, switching and dimming) to achieve a projector on/projector off ratio of 50/1 (for television this should include reflections on the screen); simultaneously, the system should provide optional illumination of a small section of chalkboard, and note taking light (see above) and light for the lecturer.

Environmental:

Overall design should organize space by:
- providing focus at areas of principal activities
- defining structure by light gradients
- highlighting displays, murals, etc.

Distraction from tasks at front of room and heads-down tasks should be minimized by:
- eliminating light sources from field of view, and keeping illuminated room surfaces within field of view of less brightness than focal points (unless design relevance permits illuminating them to greater brightness);
- or, if some or all of the light sources cannot be concealed, control distraction by:
  - minimizing source brightness, increasing background brightness
  - placing maximum brightness at maximum displacement from line of sight

*The minimum level of information represented by the requirements of speed reading, for example, may be defined by TII of 1.0.

minimizing size of source
organizing with an orderly geometric pattern
avoiding fixtures that are ugly, out of character

Visual rest centers and orientation should be provided by a window view (not of sky alone) or points of interest within the room.

Gloom should be avoided by counterbalancing window brightness and providing expected daytime balance of light in windowless spaces in the following manner:

illuminating ceiling and/or walls
using light colors in the right places

Inappropriate color rendition should be avoided by not using cool-white fluorescent lamps.

In summary, an environment should be created that looks and feels right for the purpose, and is consistent with the overall design concept of the building.

Weighting of lighting objectives for consideration of alternate design solutions:

Task: 50%
Environment: 50%

SPECIMEN 3. INDIVIDUAL ROOM EVALUATION: DINING ROOM

Space: dining room

When is the space used?

_______% during the day
_______% at night

What is the space used for?

Principal activities: eating
conversation
dances
receptions

Secondary uses: lecture program (projections)

Accessory activities: cleaning up

What are the lighting objectives:

For the tasks: eating and reception requirements are minimal; if room looks inviting there will be enough light.

for cleaning up, if room does not appear dark during the daytime, there will be enough light; when only a very dim environment is desired, a separate lighting system for maintenance can be provided.

Environmental: objective of lighting dining room is to create visual environment that appears appropriate for the activities; very little artificial light is required at night or during the day when daylight distribution is well-balanced, with highlights as desired; illuminate to eliminate daylight gloom, particularly with daylight distribution from overcast sky conditions.

spaces that appear too bright at night should be avoided; this can be achieved by careful consideration of switching and dimming, as well as the basic design.

thus, the major demand is to balance imbalanced daylight to illuminate the surfaces of interest, people, table tops, murals, featured wall areas, structure, etc.

lighting equipment itself should be highly conspicuous only as a positive design choice (considered as sculpture and a worthwhile object of interest).

for color considerations, it is important to avoid use of cool-white fluorescent lamps.

safety: there should be a minimum of 0.25 fc at any point with substantially more than this, and better yet a high-light, at points of danger, such as stairs.

Weighting of lighting objectives

Task: 10%
Environment: 90%