DESIGN OF OFFICE BUILDINGS BASED ON LESSONS LEARNED FROM CALIFORNIA'S INNOVATIVE STATE OFFICE BUILDING PROGRAM

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Summary

Energy conservation efforts in new office buildings have been substantial since the 1973 Arab Oil Embargo. A variety of techniques including daylighting, energy-efficient lighting systems, solar shading, active and passive solar heating and cooling, and ventilation system modifications have been employed. Very little data is available to evaluate the results of the use of these and other building energy conservation techniques.

The project reported here represents an effort to evaluate the energy and occupancy effects of energy conservation design in eight new State of California office buildings designed and constructed in the years 1977-1983. When completed, the project will provide valuable data and guidance to designers of energy-conserving office buildings. These guidelines will assist in integrating energy-conserving technologies with other habitability and environmental quality design goals. This paper reports project progress and results to date.

Introduction

Project Purpose

The purpose of the project described here is to develop information that will optimize the efforts of architects and engineers to jointly make design decisions which will result in energy-efficient, healthy, comfortable and productive office buildings.

Project Focus

The project includes investigation of eight State of California energy-efficient office buildings constructed between 1977 and 1983. The eight buildings comprise approximately 1.5 million sq. ft. and house approximately 7,000 state employees. These buildings, most of which have been published, include a variety of innovative energy conservation technologies, such as active and passive solar systems for heating and cooling, thermal mass, chilled water storage, rock thermal storage beds, closed and open atria, night ventilation, de-stratification fans, external shading devices, daylighting, innovative electrical lighting sources and control systems, computer and conventional energy-management control systems, etc.

These buildings represent an outstanding research opportunity for several important reasons. There are similarities in the populations occupying them and the types of activities which occur in them. There is a substantial "control" population available in other state office buildings. And the buildings themselves represent an important experiment with energy-conserving building technology in the context of a building program calling for extremely habitable office environments.

Project Progress

Work to date has included site visits to the eight buildings, interviews with various individuals responsible for operating and managing the buildings, identification of factors to be included during more comprehensive data-gathering and building performance modelling, and a series of five seminars. The seminars were held with the participation of over 30 individuals including various members of the office building design firms and their consultants, representatives of state government agencies involved in project planning, design, construction or operation, and leading researchers in the field.

The five seminar topics were as follows:

1. Architects and the Process of Design for Energy-Efficient Buildings;

2. Lighting and Illumination Energy, Comfort and Health;

3. Ventilation and Air Quality, Comfort, Health and Energy-Efficiency;

4. Occupant Satisfaction, Comfort and Health;

5. Summary and Recommendations for Future Work.

This paper presents the results of the seminar discussions, the on-site investigations, and the literature reviews. Additionally, it describes some of the analytical tools being developed currently. These tools and the information gathered to date can assist architects and engineers during the design process. Future work will include refinement of analytical tools and evaluation of building performance.

Project Goals

1. Post-occupancy evaluation of eight state-of-the-art office buildings. Document the performance and evaluate it against the program statement.

2. Development of a design tool to aid architects and engineers to design buildings that act synergistically to provide energy-efficiency, user comfort/health, and user productivity and quality work. Make visible in a systematic way many of the different trade-offs that are available to designers. It should be a design tool, not a design methodology. It should be a design tool that can be integrated into any design methodology.

The purpose of the project described here is to develop information that will optimize the efforts of architects and engineers to jointly make design decisions which will result in energy-efficient, healthy, comfortable and productive office buildings. It will assist the architect and engineer in coordinating the design process. Coordination really entails taking the responsibility for how everything fits into the building.

Project Process

Three phases of the project have been completed to date as follows:

1. Field investigation (preliminary)

2. Seminars

3. Literature review

The project process is represented graphically in the figure below.

I	II
Field investigation	Model development
Program investigation	Model "testing"

Figure 1. Project Process

Project Observations to Date

Field Observations: Site Visits

General Findings. The following points represent our general assessment of the eight buildings based on brief site visits.

1. On the whole the buildings are operating satisfactorily with respect to environmental conditions provided within them.

2. Building operators hesitate to operate the buildings for maximum designed energy efficiency when user complaints are received and perceived to be affected.

3. The "higher" the technology, the more prone it is to break down.

4. A simple supply-return air balance is inadequate to assure satisfactory performance of the HVAC system.

5. There are no inherent, generic problems in "passive" designs for heating, cooling and ventilation. These systems appear to be "self-correcting" when used.

Specific Problems. The series of brief on-site visits has revealed some specific problems in certain buildings which vary from building to building. They are listed below:

1. Air balance is (was) off in many of the buildings when they were first occupied.

2. Supply air register defects were common.

3. Return/supply air design and operation was not providing adequate air circulation in the occupied spaces.

4. Low lighting levels specified for energy conservation are not being maintained. User complaints and lighting equipment problems are apparently the main reasons.

5. Glare problems are common.

6. Automatic dimming controls are ineffective due to manual overrides and technical problems with equipment.

7. Buildings are generally not being operated as designers anticipated. This is often the result of the discontinuity between designers and operators.

8. Population density within buildings has been increased from the programmed levels.

9. Partition modes have been changed to accomodate occupancy changes and personnel changes.

10. Some air handling systems are noisy. Some possible causes include construction flaws as well as design errors.

11. Stuffiness is reported where air volumes are low and minimum outside supply air is used.

12. Automated sunshading devices break down; they don't always perform in a "user-logical" fashion--one that appears logical to the users.

13. Energy use monitoring by operators is not broken down in a way that is useful to designers or researchers.

Comments from Building Operators. In the course of the site visits, the following comments were made by building operating personnel (managers, engineers, maintenance staff):

"Innovation is scarey to old timers..."

(This) "...building can be run by computer totally, but it's not a good idea..."

"Cost of energy, not amount used, is critical..."

"...simple building to operate."

Seminars

The following conclusions were drawn from the discussions at the seminars.

The building design process has many existing variations, no need to invent or try to determine the "best."

There is a clear need to involve building operators in the design process (not just via "approvals").

Better consideration of user needs is required.

Questions were raised whether computer control which provides infinite operational variations equates with user control? The answer relates to who controls the computer.

Do opening windows which are locked and inaccessible equate with the unsealed building image specified in the program? This query pointed to the conflict between the program and the actual operation of the building.

Training manuals should be budgeted as routine elements of building development.

Literature

On Research Methods. There appear to be four basic research methods used for post-occupancy evaluation and building diagnostics. These are as follows:

1. Survey research: Standardized survey instruments are administered to building occupants. They are analyzed using social science statistical techniques.

2. Interviews: Structured or unstructured interviews are used. They are administered systematically or randomly. Sometimes they are administered to participants in survey research on a sample basis.

3. Observations: Environment and occupant behavior are both subjects of this research method. Systematic observations are increasingly common, often assisted by scaling of subjective judgments. Mapping of behavior patterns, spatial distribution of activities, and other observations developed by urban and architectural geographers are common.

4. Measurement: Building diagnostics and concern for indoor pollution have increased the use of physical measurements in building evaluations. Temperature (air and surface radiation), humidity, air movement, air pollutants, ventilation rates, lighting and light pollution, and noise are commonly measured.

Research methods are increasingly inter-disciplinary. They involve social scientists, designers, physical scientists, occupational health researchers, and others.

Research Findings

There is consistency in the identification of problems by occupants of office buildings evaluated by other researchers. These include problems with visual and acoustic privacy, often related to open plan offices, the proliferation of office machines, and the move of people from enclosed offices to open offices.

Complaints about lighting, fixed windows, no windows at all, uncomfortable or inflexible furniture, inadequate space or privacy, and the inconvenience of amenities such as break rooms and restrooms are common in newer buildings.

It appears that open plan offices work better for some tasks than others. This suggests the need for careful programming and consistency between program and actual space use.

Air quality and health complaints are increasingly reported as problems by other researchers. The current interest in air quality has both stimulated and been stimulated by these reports.

There is increasing agreement about the need for standardized research methods and variables so that results may be compared across studies. Such comparison is difficult or impossible now due to the lack of such standards.

Project Conclusions to Date

These conclusions are on buildings where the program calls for healthy, comfortable, and productive working environments.

1. There is a need for building Post-Occupancy Evaluation (POE) for the eight state buildings. It is clear that there is much good information available which would be useful to the design professionals involved in the office building design, particularly those which are low-rise, energy-conserving.

Post-occupancy evaluation is needed and desired by the affected design professionals. Without such evaluation, valuable insights may not be obtained and improvements in further design work will be limited by an absence of data indicating success of design decisions. Architects, occupants, operators, visitors and building owners (in the case of these buildings, the people of California) will not derive the potential benefits of the experimental program which resulted in the eight buildings.

A better fix on actual ventilation patterns is needed by designers and engineers, as well as building operations personnel.

2. Effective design processes should include different participants or use the current participants differently. The views, needs and knowledge of building operators are not adequately considered in the current process. Efforts to utilize building users (occupants, operators) are limited by changing personnel between the time design is done and the time the structure is completed and occupied.

gners need to be better aware of likely management /operational needs and strategies--they (designers) cannot control what occurs in the completed structure by "normal" training of staff and providing customary operational manuals.

3. Simplicity and flexibility in systems and their operation are keys to achieving operation of the building consistent with the design intent. Many factors are likely to change between design and occupancy, so flexibility is critical. If it is lacking, changes will not necessarily build on the potential environmental quality or energy efficiency.

4. It is necessary to pay more attention to the impact of various major design decisions on other design decisions to avoid conflict and sub-optimization. Guidance for designers is necessary to assist in this task. A project decision modelling tool would have generated better operational designs for the eight state office buildings.

Architects and engineers need to make their design choices based on better understanding of the impact of the choices on the final building product, e.g., most energy efficient light fixtures may create ventilation flow problems.

5. More comprehensive ventilation design is a key element for buildings which will meet program goals of energy-efficiency as well as healthy, comfortable, and productive office building environments.

6. User manuals are needed to effect the optimal use of innovative building design, particularly where user participation is necessary to the successful operation of the buildings.

7. Building operation should be thoroughly tested prior to occupancy. Hurried schedules and the pressures of completion often result in incomplete check-out of building systems. This practice often results in buildings which are not sufficiently ready for normal occupancy.

The Model

Model Development to Date

The model consists of a set of key actors, the critical variables, and the description of the relationships between the variables. The intent of the model is to assist designers in recognizing the connections and relationships between critical design variables during the design process. The elements of the model are identified below. Further work is required to refine the list of model components and to improve our understanding of their relationships. These tasks will be undertaken during the next phase of the project.

Key Actors

Occupants
- Employees
- Employers
- Visitors

Designers
- Architects
- Engineers
- Landscape architects
- Space planners
- Interior designers
- Specialized consultants

Clients
- Tenant agencies
- Buildings & grounds division, D/general services
- Legislature
- Public

Management
- Building manager
- Building engineer
- Maintenance staffs
- Buildings & grounds directorate

Critical Factors (Users)

Lighting	Noise
Temperature	Privacy
Air supply	Space
Air quality	Furniture
Humidity	Equipment
Control over space	Control over environment
Security	Views, visual relief/escape
Exit options: emergency, relief/recreation	

Critical Factors (Management)

Reliability
- Mechanical
- Lighting
- Security
- Maintenance

Cost
- Energy
- Maintenance
- Durability
- Replacement cost and feasibility

Flexibility
- Use change
- Operational variations-hours, climate, zone

Safety

Future Work

Current plans call for collection of data on building performance using some of the research methods described above. Definition and refinement of the methodology to be used during field work must be completed. Data will be gathered on building energy performance and its impact on users. A variety of research methods will be used to generate a cross-variable correlation matrix.

The model will be expanded into a functional tool for designers. It will also prove valuable to researchers and policy-makers interested in the relationships and trade-offs involved in energy-efficient office buildings. It will be validated by cross-comparison with field data. After validation, it will be documented in formats which will facilitate its utilization by design professionals.

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