ENVIRONMENT DESIGN GUIDE

OPERATING A BUILDING FOR THE NEXT 20 YEARS

Lex Dewar

SUMMARY OF

ACTIONS TOWARDS SUSTAINABLE OUTCOMES

Environmental Issues/Principal Impacts

- The occupancy stage of a building accounts for around 65 per cent of the total life cycle cost of a building.
- Lighting that enhances occupant comfort and satisfaction can increase productivity and add value to the facility.
- Lighting that can respond to change will increase service life and reduce business disruption due to services alterations.
- Design for maintenance will ensure the lighting continues to meet the required service standard at an acceptable recurrent cost.
- Design for operational efficiency can reduce energy consumption and ongoing operational costs.

Basic Strategies

In many design situations boundaries and constraints limit the application of cutting EDGe actions. In these circumstances designers should at least consider the following:

Occupant comfort

- Task oriented lighting design
- Provide opportunity for user control
- Optimise daylighting

Occupant change

- Design for flexibility, modularity and inter-changeability of light fittings
- Consider continuity of supply and adaptability of fittings in specifications

Maintenance

- Select lamps and fittings to reduce lamp replacement costs
- Consider maintainability of the lighting systems such as access, durability and occupant disruption.
- Include programmed cleaning and maintenance regimes in handover documentation

Operation

- Include multiple levels of metering and control.
- Specify high efficiency lamps and luminaires
- Build in both manual and automatic control systems to fit the user profile

Cutting EDGe Strategies

- Utilise life cycle costing techniques when evaluating lighting alternatives.
- Use lighting to enhance spatial definition, way finding and visual variance.
- Involve users and managers of buildings in the design and delivery process.
- Use predictive maintenance modelling techniques for selection of light fittings.
- Use sustainability criteria when selecting lamps and fittings.
- Integrate lighting systems into a comprehensive building management system.
- Include education and training programs as part of the building orientation.

Synergies and References

- *BDP Environment Design Guide:* GEN 10, GEN 51, GEN 61, TEC 3, DES 1, DES 6, DES 7, DES 34, DES 61, DES 62

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The operational stage of a building accounts for up to 65 per cent of the life cycle cost. However the ability of the Facility Manager to deliver a high performance building environment is largely governed by the initial design, construction and commissioning stage. This Note provides strategies for the design of lighting systems that will enhance performance in use and contribute to a more sustainable building outcome.

1.0 INTRODUCTION

The purpose of buildings is to provide meaningful places to support people and the activities that take place there. Often the design of a building's environmental system is technically and structurally competent, but fails to meet the changing demands over time of both the users and managers.

1.1 The Facilities Management Context

Unlike other building related professionals, those working in facilities management (FM) focus on managing buildings once they are in use. This requires an understanding of the complex interrelationship of functions and activities that occur within buildings. A building's capability is therefore measured on how all the elements work together – not on the performance of one isolated system.

Facilities management can be seen as operating at the interface between buildings, technology and the people and business that use them. As a stakeholder in the building delivery process they potentially can bridge the gap between the design/build process and the use/maintain phase of a building. In this role they are able to act as a conduit for the transfer of knowledge about what works in practice and what doesn't.

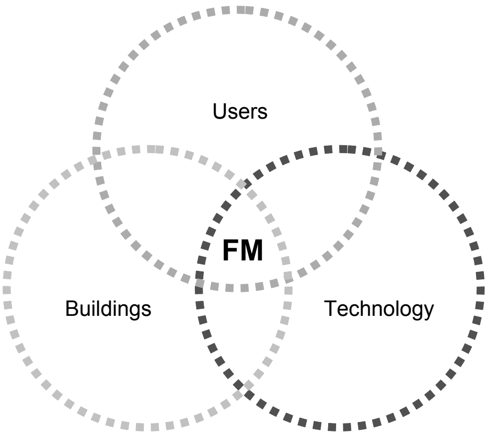

Figure 1: The facilities management (FM) context

1.2 The Case for a User Driven Approach

Design and construction costs for a typical commercial building account for only about one-third of the total cost over the life of the building with operation and maintenance contributing two thirds of the expenditure (US General Services Administraion, Office of Real Property). Consideration of ongoing running costs should therefore be an integral part of the decision making process in the design and construction stage.

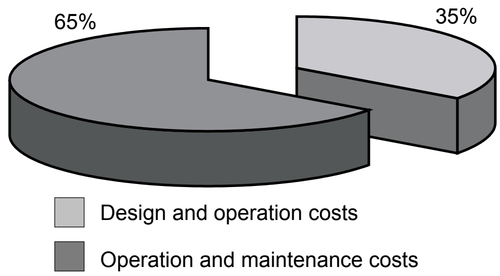

Figure 2: Whole-of-life cost of buildings

When you then add into this equation the investment in human capital (the building occupants) over the same period, the costs attributed to the procurement and management of the physical infrastructure are comparatively small representing only about 9 per cent (AS/NZS 4536:1999).

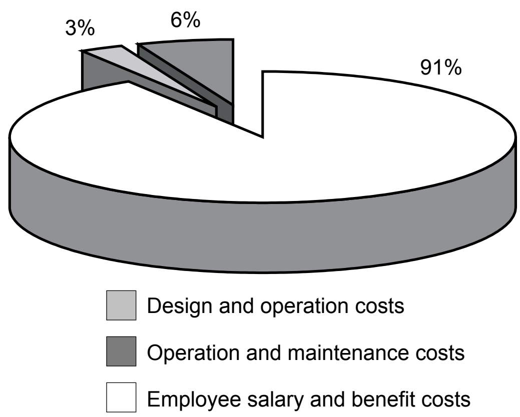

Figure 3: Whole-of-life cost of buildings (including human capital)

What this tells us is that the effectiveness of buildings and their environmental systems should be measured by their ability to support the building users. An incremental increase in productivity attributable to the environmental systems will have a significant cost benefit to the occupants over the life of the building. This creates a completely different value proposition when making decisions about capital expenditure on buildings. Owners and tenants of buildings could therefore view their physical assets as a means to add value to their businesses.

2.0 BUILDING LIFE CYCLE

Typical stages of a building life cycle are planning, design, construction, occupancy/use, modification/churn, refurbishment and disposal. Consideration for all these stages when planning and designing buildings can result in a more sustainable outcome. At the inception of a building project many of the decisions are made that will influence the later performance of the building when in use. These decisions should be informed by reliable knowledge about how the building and its components will perform over its life. The desired outcome is better decisions aimed at balancing the need for flexibility and durability with the constraints of budget, time and buildability.

Typical components of buildings and their design life are represented in Table 1. The higher up the table, the longer the design life and the more difficult and costly they are to change. Conversely the lower down the table the shorter the life span and more adaptable to change they need to be. The criteria for design and selection of each element should be based on its use over time. For example, structure and building skin would be designed to accommodate changing demand over time but without need for modification, whereas criteria for design of the 'scenery' (furniture and fittings) may be to accommodate frequent changes.

Table 1: Building component life

Building Component	Life	Change Profile
Site	Infinite	Low
Structure	50 yrs +	Low
Envelope/skin	30-50 yrs	Medium
Services	10-25 yrs	Medium – high
Settings (fitout)	7-10 yrs	High
Scenery	5 yrs +	Very high

2.1 Life Cycle Costing (LCC)

Definition

The principle of Life Cycle Costing (LCC) is to consider the total cost of an asset over its effective life. This would include the initial design and installation cost, but also the ongoing running costs. A definition of LCC is 'the sum of the acquisition cost and ownership cost of a product over its lifecycle' (FMA and Standards Australia, 2001).

Expressed as an economic equation:

$$LCC = (AC - TD) + (OC + RC) - RV$$

LCC – Life cycle cost
AC – Acquisition cost
TD – Tax depreciation entitlements
OC – Operating and maintenance cost
RC – Replacement/disposal/upgrade cost
RV – Residual or salvage value

Establishing the effective life of an asset relies on economic and performance predictions and establishing a life expectancy. This will vary depending on the definition of 'life' that is adopted and could include component life, operational life, functional life, technical life, economic life and so on. The use of a triple bottom line accounting approach (using economic, environmental and social measures) will help to ensure a more balanced view of what constitutes the life of an asset.

2.2 LCC of Lighting

When applied to lighting systems a simple model can be developed to assess their total life cycle cost (Figure 4). When we overlay historical data on the costs for lighting installations we see that the capital cost (including design, installation and commissioning) accounts for about 35 per cent of the total life cycle cost. The remaining 65 per cent is attributed to the ongoing cost to use and maintain it.

Decisions made in the initial stage of design, installation and commissioning will have the greatest bearing on the ability to manage the other 65 per cent of the costs over the life of the lighting system. The most value is gained through the application of LCC techniques in the early design phase; however this is also often when the least amount of information is known about the ongoing operation of the building. This can be addressed by:

- Inclusion of stakeholders in the design process who are responsible for operation and maintenance of the lighting. This may not have

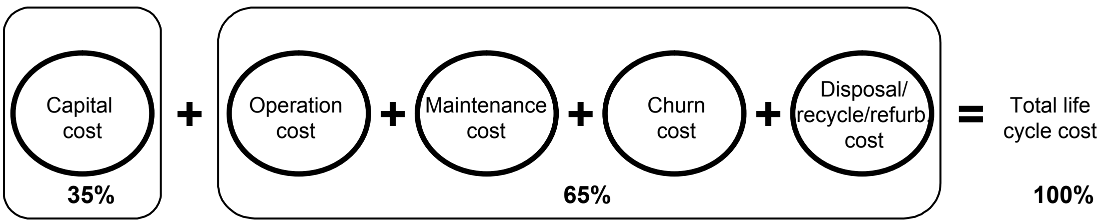

Figure 4: Life cycle cost of lighting

been determined at such an early stage in which case it may be necessary to include contractors or consultants with previous experience on similar projects to provide expert advice.

- Use of predictive modelling tools aimed at producing whole of life cost profiles.
- Inclusion of consultants skilled in the use of LCC techniques.

3.0 AREAS OF INFLUENCE FOR LIGHTING PERFORMANCE

There are many areas of influence the designer can have over the ongoing performance of the lighting system. This Note focuses on four key areas – occupant comfort, occupant change, maintenance and operations. These can further be classified as either demand drivers or supply influences as shown in Figure 5.

The ***demand drivers*** contribute to the service level requirement. These help to articulate what the lighting system is expected to do and its required level of performance. The ***supply influences*** are the factors that contribute to the lighting system meeting these expectations on an ongoing basis.

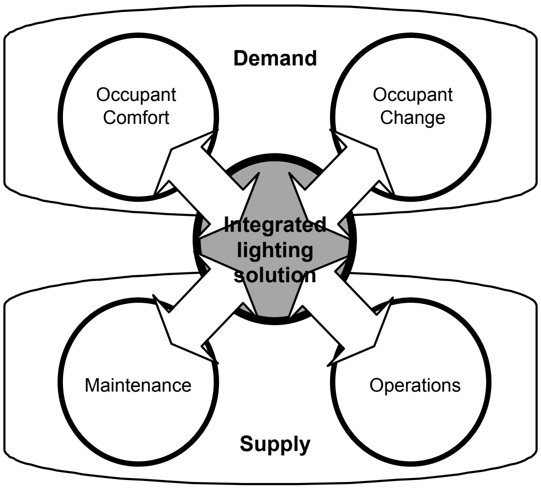

Figure 5: Areas of influence for lighting performance in use

3.1 Occupant Comfort

According to Dr Jacqueline Vischer, a leading environmental psychologist, 'Comfort as a basis for setting environmental standards developed out of recognition of peoples' need to be more than simply healthy and safe in buildings they occupy. Once health and safety are assured, users need environmental support for their work. Comfort links the psychological aspects of workers likes and dislikes with concrete outcome measures such as improved task performance and worker productivity' (Visher, 2004).

Vischer further identifies three aspects of comfort – physical, psychological and functional. Providing physical comfort requires that buildings are habitable and occupants are not exposed to extreme environmental conditions. This is typically achieved through lighting design that complies with statutory requirements.

Psychological comfort considers how effective the space is in helping users perform their task. Lighting must be fit for purpose by addressing and responding to the tasks and activities within the building. Related comfort dimensions include spatial comfort, visual comfort and lighting quality.

Functional comfort addresses higher order needs for social, intellectual and cultural fulfilment and encompasses aspects of privacy, status, empowerment and control. Lighting design can support these needs through the inclusion of personal lighting control, creation of visual variance, interest and visual enclosure within the interior environment.

3.2 Change

The physical result of change is churn. Churn is defined as:

'Internal accommodation rearrangements undertaken in response to changing organisational and functional requirements', (FMA and Standards Australia, 2001).

The ability of building systems to respond to change has emerged as a key performance indicator for buildings in use. If a building system fails to cost effectively adapt to change it can result in increased physical asset costs and added disruption to the occupants. Adaptability is largely driven by the need for organisational agility – the degree to which a business can respond to the market. Change drivers may be organisational, functional, technological, economic and regulatory or user initiated. Lighting systems must be capable of responding and adapting to the demands of change over the life of the facility.

3.3 Maintenance

'Best practice' asset maintenance management aligns a building's maintenance policy with an overall asset strategy. The policy is aimed at ensuring value for money, protection of the asset/resource value and satisfying statutory and legal obligations. The benefits of maintenance planning include long term reduction in the cost of maintenance, increased performance, longer asset life and improved perception by building users.

Maintenance performance is assessed in terms of the current state compared to an agreed standard. An agreed standard may be measured in terms of economic criteria, functionality, statutory compliance, service level (such as response time or downtime) or other measurable performance indicators.

All lighting requires maintenance in order for it to satisfy the agreed service standard. Specific considerations for lighting include:

- Effectiveness – Lighting should continue to meet the requirements of the activities and tasks performed in the building.

Table 2: Lighting strategies for occupant comfort

Strategy	Benefit	Implementation
Task oriented lighting design	Lighting solution is suited to the task required to be performed in the space and provides appropriate lighting level, degree of control and lighting quality.	Involve end user in lighting design process. Selection of light fittings and lighting layout design that match lighting quality with activities and tasks.
Optimise daylighting	Access to daylight has both positive physiological and psychological benefits for building occupants.	Design of building massing, orientation and 'skin' to optimise daylight access and reduce negative impacts of thermal loading and glare.
Greater user control of lighting	Improves user satisfaction with the lighting and extends the threshold of tolerance when conditions are below optimal.	More light switches and dimmer controls with the ability for localised control. Where electronic control systems are used ensure they are 'user friendly' and that occupants understand how to use them. Consideration of user controlled task lighting in conjunction with ambient lighting.
Enhanced understanding by building users	Improves understanding of the purpose of the lighting system and ultimately greater ownership and responsibility for its effectiveness.	Establish a user-operating guide. Provide education and training on the features, capabilities and how to use the lighting system as part of a building orientation program.
Improved responsiveness	Improved response time to change and/or dealing with complaints increases user satisfaction with the building services.	More intuitive control systems for both users and facilities managers. Establish agreed service levels with users. Provision of management resources commensurate with the building complexity.
Reduce glare	Glare can cause visual discomfort through eye strain and headaches with a resultant negative impact on productivity.	Operable control mechanisms for natural light including diffusers and blinds. Consideration of contrast and re ectivity of both interior and exterior surfaces. Use of low glare fittings.
Visual variance	Variation in visual field can reduce visual fatigue.	Utilise different lighting levels across the building spaces that are appropriate to the use. Build in the opportunity for distance views.
Spatial definition and orientation	Lighting can assist to define building form and function as well as enhance orientation.	Use lighting design to articulate different activity zones, enhance way finding and reinforce spatial hierarchies.

- Efficiency – Maintaining an acceptable light output to energy consumption ratio is dependant on a number of factors including lamp replacement and luminaire cleaning regimes, control systems and user intervention.
- Compliance – Ability to maintain statutory compliance should not require high maintenance input and subsequent increased risk for the asset owner.
- Responsiveness – Maintenance of the lighting can be achieved within acceptable response times and with minimal downtime.
- Maintainability – Lighting maintenance is cost effective without undue reliance on specialist equipment or technical expertise. Where specialist intervention is required to optimise performance then adequate documentation, training and resources should be allowed for. This will need to be articulated to those responsible for managing the building. Design can have a strong influence on maintainability of the lighting systems. Consideration for accessibility and general ease and simplicity of the ongoing maintenance can significantly improve the cost effectiveness of the outcome.

3.4 Operation

Once installed and commissioned the ongoing operation of lighting systems is effectively handed over to the Facility Manager and the building occupants. Both have a joint responsibility for its effectiveness. However, at best only the Facility Manager would typically be trained in how to use the lighting system. Not involving the occupants in the process may result in the lighting system never reaching its full design potential. Typical outcomes of a lack of understanding and ownership of the lighting can vary from increased complaints and reduced energy efficiency to more extreme cases of bypassing control systems and even deliberate sabotage.

Issues for consideration with respect to operation of the lighting include:

- Energy efficiency – Energy efficiency during the operational phase of the building is achieved through maintaining the design performance

Table 3: Lighting strategies for occupant change

Strategy	Benefit	Implementation
Flexibility	Provides the ability to quickly and cost effectively re-configure lighting to meet occupant driven changes.	Adopt a 'plug and play' approach where appropriate to allow changes by non-skilled personnel. Design in the ability to change the characteristics of the lighting design to suit new activities and tasks.
Planning modularity	This can significantly reduce the cost of churn by eliminating the need to make expensive alterations to building services.	Develop a planning rationale for the building spaces that can allow churn to occur without the necessity to change building services.
Continuity of supply	Avoiding early redundancy of fittings and components can extend the operating life and maintain consistency when new fittings are required.	Utilise recognised suppliers with a history of long term product support. Consider using a standing offer supply arrangement and/or retaining maintenance stock of fittings.
Adaptability of fittings	The ability to change fittings in response to new and changing demands will reduce premature redundancy.	Select fittings of simple robust design that allow for future retrofitting/upgrades due to such demands as technology and regulatory changes.
Interchangeability	Interchangeability of fittings and components can increase re-useability when change occurs.	Consider using a 'family of fittings' rather than one-offs. Ensure light fittings will interface with other related building elements such as ceiling and furniture systems without the need for modification.
Documentation	Good documentation of the lighting design and its intent and purpose can help to ensure it is carried forward into the operational phase of the building's life.	Include detailed documentation, specifications and as-built drawings of the lighting system at the handover stage.

of the lighting and continually adjusting the systems with the usage profiles and patterns. This relies on the ability to measure and report on the performance of the lighting system made possible through lighting management systems.

- Control – Control can be viewed at two levels. Firstly localised control by building occupants, and secondly control at a whole of building / portfolio level. Localised control has been covered under user comfort. Overall building control is largely dependant on the inclusion of lighting control software usually integrated within a building management system.
- Training and induction – Orientation of the building and its environmental systems will encourage understanding and ownership for their ongoing performance. The transfer of knowledge about the lighting systems will need to be relevant to the user group. Those responsible for the higher level management of the overall lighting systems will require quite different and more detailed knowledge than the occupants. Well thought out and intuitive designs can avoid the need for complicated systems that are difficult to operate. Often simple solutions will be better accepted.

4.0 IMPROVING THE DELIVERY PROCESS

Adopting a 'whole-of-life' approach to lighting systems will challenge the traditional process of design and delivery of buildings. A new approach is needed that bases design and capital investment decisions on creating building capability for the owners, managers and users. To achieve this may require establishing a number of ground rules in the delivery process:

- Establish an integrated approach that avoids design professions operating within 'silos' of expertise. Fragmentation can lead to a short-term problem focus rather than a long-term outcome focus.
- Avoidance of highly contractual and adversarial relationships between the parties in the procurement process. These conditions can result in 'lowest common denominator' approach with short-term economic gain at the expense of long term building performance.
- Inclusion of stakeholders in the design process who are responsible for using, operating and maintaining buildings. Traditional entry point for Facilities Managers is at handover/commissioning stage at which point the majority of decisions have been made that will impact on the ability to operate and maintain the building. Reliable data

Table 4: Lighting strategies for maintenance performance

Strategy	Benefit	Implementation
Optimise lamp life	Reduces frequency of lamp replacement.	Specify lamp types appropriate to task/activity/service environment with consideration for maximum lamp life.
Maintain lighting performance	Ensures the lighting meets the agreed service standard on a continuous basis.	Establish programmed cleaning of the lamps and fittings to maintain light output. Establish scheduled group re-lamping practices.
Establish agreed service level	Enables the appropriate allocation of maintenance resources to avoid over or under servicing. Promotes clear understanding between users and managers of buildings on service expectations.	Establish a service level agreement with tenants for the lighting system including key performance indicators.
Maintainability	Minimises the cost of maintaining the lighting system through good design practices.	Select fittings that are fit for purpose. The location, operation and maintenance needs should in uence the type of fitting and lamp and so balance capital cost with maintenance cost. Consider ongoing maintenance requirements at the design stage including accessibility for servicing / replacement, durability and ability to replace components.
Disposability	Reduce the cost and environmental impact at end of life.	Specify fittings that have been designed for disassembly to enable recycling of materials. Specify (where possible) equipment and fittings that have materials with low embodied energy and do not utilise toxic or hazardous substances in their manufacture. Use accredited maintenance contractors that dispose of redundant lamps responsibly.
Condition assessment and preventative maintenance	Provides quantitative and qualitative information about lighting condition to establish a preventative maintenance program aimed at reducing costly unplanned/reactive maintenance.	Use a recognised method for assessing the condition of the lighting systems. Utilise the data to establish a whole-of-life preventative maintenance program.

on the performance of buildings is necessary to inform the design and specification process.

- Accept that buildings are a resource not simply a commodity. This approach recognises that buildings can add value to the business and people that use them through increased productivity, staff satisfaction and occupant health. The trend toward investor based ownership rather than owner/occupier has threatened this view of buildings.
- Adopting a broader perspective of building performance to include social and environmental returns, as well as economic returns. Too much emphasis on lowest capital cost solutions can result in the de-skilling of the design process and have a negative effect on long term performance of the building.
- Utilise life cycle costing techniques and other cost benefit methodologies to evaluate capital cost decisions against the long term benefits.
- Provide the opportunity for the transfer of knowledge between design and construction teams and the people who will manage and use the building. Better understanding of how to use and maintain the lighting systems will create greater ownership and a shared understanding of performance expectations.
- At handover stage of a building or fitout provide an orientation program for users and managers to become familiar with how the lighting system works.

5.0 SUMMARY

Designing highly effective lighting systems requires a long term view of their performance in use over the life of a building or facility. Once installed and commissioned the lighting will be expected to meet the demands of change and user comfort requirements. To successfully achieve this, the design will need to consider ongoing maintenance and operational issues.

Table 5: Lighting strategies for operational performance

Strategy	Benefit	Implementation
Reduce energy consumption	Reduce operating costs and minimise environmental impact (greenhouse gas emissions)	Exploit natural daylighting and consider daylight sensors to reduce the need for artificial light sources. Avoid over lighting. Include automatic controls such as occupant sensors. Provide local switching for occupant control. Develop a space zoning lighting strategy that matches control measures with use patterns. Specify high efficiency lamps, control gear and fittings. Select interior colours that reduce the need for lighting.
Improve control	Provides the ability to track energy usage for the purpose of improving efficiency. Also provides the opportunity for internal charging (user pay) as a means to reduce overall consumption.	Circuits should allow for sub-metering of individual zones and/or oors.
Enhance understanding of lighting management	Improves the ability to effectively manage and maintain the system at optimal levels. Improves ownership and responsiveness to deal with problems.	Provide a comprehensive M&O manual on completion. Include mandatory education and training by suppliers and/or installers at handover stage.
Improve integration with other building services and architectural systems	Demonstrates the interrelationship between the separate systems and how they perform as a combined building system. Enhances measurement, control and reporting to enable informed decisions about the lighting systems.	Consider integration of the lighting within with the overall Building Management System (BMS).

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BIOGRAPHY

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