



U.S. General Services Administration

DESIGN GUIDE FOR OPERATIONAL EXCELLENCE

applying lessons learned through post occupancy evaluation



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For Public Distribution

Cover photo: The U.S. Army Corps of Engineers (USACE) new Seattle District Headquarters Building 1202, at Seattle's Federal Center South (FCS), was completed in February 2013. This \$75 million, 209,000-square-foot project replaced an early 1940s, obsolete large warehouse structure. The project is designed to be one of the most energy efficient office buildings in the entire GSA PBS inventory.

Design Guide for Operational Excellence

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I. INTRODUCTION

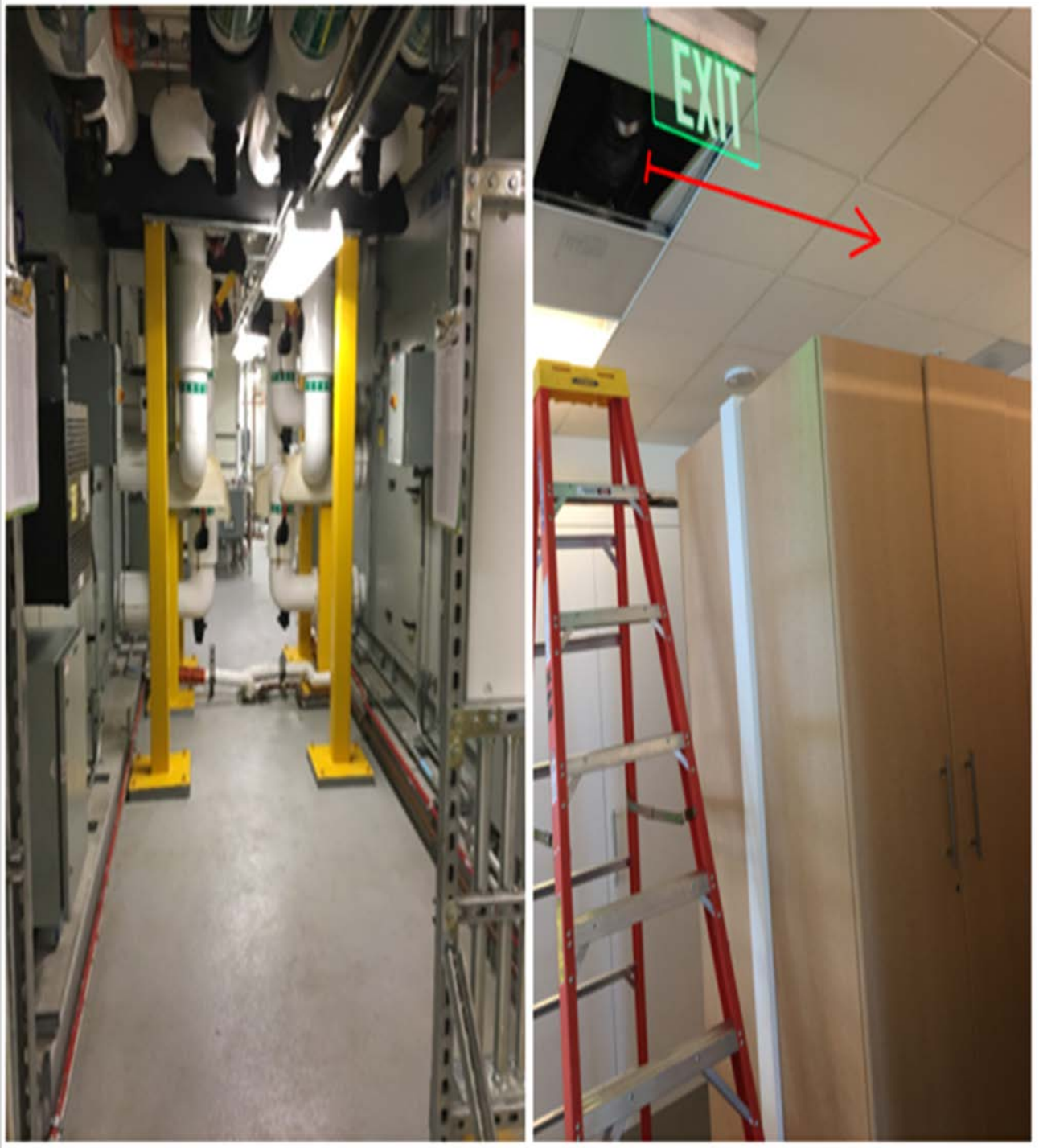
“Lessons Learned” is a common concept in the practice of design and construction of buildings. We build a building, revisit the project after completion to find out what worked and what did not work, and apply the lessons by repeating what worked and avoiding what did not. The lessons should change continually, as we incorporate old lessons into an ever-improving professional practice, and identify new, more nuanced lessons to add. We share these lessons with all to assure that the lessons are not simply identified, but also learned and turned into more successful practices. Every lesson that we actually learn turns the curve towards more affordable, durable, and higher-performing buildings.

The purpose of this document is to turn the identification of lessons into actual learning to effect a positive change in design outcomes. The National Institute of Building Sciences conducted the FY2018 Post Occupancy Evaluation (POE) Program for the U.S. General Services Administration under the direction of Patrick Fee, Director of Facilities Operations, Office of Facilities Management, Public Buildings Service, whose foresight and hands-on guidance made this project a reality. Each POE included a three-day site visit, during which the team observed and evaluated the facility’s spaces and systems from an O&M standpoint. Prior to the site visit, the team reviewed project documentation and questionnaires completed by facility staff and tenants. The team reviewed construction documentation and conducted interviews with GSA staff, operations and maintenance contractors, janitorial contractors, food service vendors, and building tenants.

The team compiled findings from each building into its own report, then condensed the six reports into a “Lessons Learned” report, for GSA use. The team then synopsisized the “Lessons Learned” into this document, designed specifically for use by GSA clients and contractors. The POE program identified a number of design principles that are important to the functionality and ultimate success of the building, based on the most important operations-oriented successes and issues identified after the buildings had been occupied for several years. A modest number of common themes were identified among the projects and compiled into one report. This document further distills those themes, and attempts to make them accessible and memorable, so that the ideas can be readily incorporated into design and construction practice.

The buildings evaluated in the POE program offer great examples of design excellence, and identifying their operations and maintenance issues should not detract from that fact. It is our intention to offer common operations issues with a non-accusatory and non-blame-based spirit, as well as to celebrate operations successes, all to move the Lessons Learned forward.

That said, we must all do our part to avoid the problems that this document now makes foreseeable. We must commit to learn these lessons and move forward. Every lesson learned must become a success replicated or a mistake avoided—before the very next building is built.



Make sure equipment is easy to install, service, and remove. Servicing these fan coil units entailed hoisting the ladder to the top of the bookcase and then through the ceiling.

II. SUMMARY: THE LESSONS

The following 20 Lessons represent the most commonly noted areas and systems where increased attention to O&M concerns during the planning and design processes show the greatest potential to save operations and maintenance time, labor, and costs, as well as increase user satisfaction and productivity.

For Site/Landscape O&M, consider the

1. Exterior Water Features
2. Exterior Plazas
3. Landscaping and Irrigation

For Envelope/Structure O&M, consider the

4. Exterior Windows/Facade
5. Canopies
6. Roofing
7. Loading Docks and Mailrooms
8. Garages and Parking

For Architecture/Interiors O&M, consider the

9. Interior Finishes
10. Atriums/Lobbies/Entrance Vestibules
11. Storage

For Mechanical/Plumbing Systems O&M, consider the

12. Occupant Environmental Controls
13. Atrium/Lobby Pressurization
14. System/Building Automation System (BAS) Optimization
15. Accessibility for Equipment Maintenance /Replacement/ Removal
16. Plumbing and Restroom Fixtures

For Lighting/Electrical Systems O&M, consider the

17. Daylighting and Shades
18. Luminaires and Lighting Equipment
19. Lighting Optimization and Controls
20. Circuit Designation and Labeling

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Site/Landscape

LESSON 1. EXTERIOR WATER FEATURES

Water features should be used sparingly, if at all. They can beautifully complement building architecture, or fail if their design doesn't take into account the attention they need over time. Poor initial installation or lack of regular maintenance can also result in water features that fall into disrepair, become a source of building water leaks, remain unused for long periods, and even become a safety concern.



It is not uncommon for water features to require extensive repair.

DO:

- **Weigh the benefits and costs.** Water features come with significant operational costs, especially in locations that regularly experience freezing temperatures or where water is scarce, and their use should be considered carefully.
- **Consider the depth.** Optimize the water depth with respect to occupant, visitor, and public safety, as well as ease of cleaning.
- **Control water spray.** Spray from fountains and irrigation systems can stain or even deteriorate adjacent wall or paving surfaces.
- **Adjust for chlorine.** Ensure compliance with requirements for preventing Legionella and other waterborne pathogens. Consider the increased risk of corrosion and reduced durability of

materials when they come in contact with chlorinated water to avoid premature deterioration or replacement.

- **Consider kids and critters.** If humans or animals potentially can access a water feature for recreation, adjust chlorination and other chemical treatments accordingly. Also, if animals can get into the water feature, make sure they have a way to get out.
- **Allow easy access.** Accessibility of plumbing and other sensitive components is important to encourage needed maintenance and facilitate winterizing.

AVOID:

- **Water over occupied spaces.** Don't locate water features over occupied spaces to minimize risk of uncontrolled water penetration as well as to simplify waterproofing details.
- **Potential projectiles.** Don't choose rocks, stones, or other elements that could be used as projectiles by protestors or vandals. Items that are light enough to throw should be avoided or secured in place.

Site/Landscape

LESSON 2. EXTERIOR PLAZAS

Exterior plazas contribute to a public building's sense of entrance, provide communal areas for occupants and visitors, and can provide space for public functions. Exterior plazas and features also can suffer from extreme environmental exposure, leading to the need for frequent maintenance.



Inadequate slope and drainage can result in paving displacement, which in turn presents a potential snow removal difficulties and a tripping hazard.

When designing exterior plazas and features:

DO:

- **Standardize the mix.** Use standard mix designs for concrete paving (and/or purchase substantial attic stock if natural stone is used) to facilitate 100-year maintenance expectations while maintaining aesthetic consistency. Document the concrete paver mix design in the project's O&M manual.
- **Carefully monitor concrete mix design, placement, and cure.** Drying shrinkage cracking typically results from high water content in the concrete mix or inadequate curing of the concrete once installed.
- **Consider cleanability.** Choose paving materials that are easily cleaned using standard pressure washing equipment and that can tolerate chemical cleaners without damage. Select low permeability and non-staining paving materials with slip-resistant surfaces.
- **Remember that size matters.** Consider the size of pavers and their joint widths for ease of maintenance. Larger pavers are difficult to remove or replace, and grout in narrow joints is more likely to fail prematurely and require replacement.
- **Consider pedestal paving.** Evaluate pedestal paving systems as an alternative to traditional mortar-set systems to reduce durability concerns. The lack of joint material reduces joint maintenance, and the ease of paver removal facilitates drain and waterproofing maintenance.
- **Take deicing into account.** Recognize that snowmelt procedures (use of deicing chemicals) can damage certain natural stone or concrete pavers, even though they would otherwise be considered durable.
- **Weigh snow melt systems.** They can be prone to frequent repair and maintenance requirements, and usually are energy intensive.

- **Educate clients.** O&M staff should make sure that clients understand snow removal contract conditions and limitations regarding priority areas for clearing and hours of operation.

AVOID:

- **Selecting untried stone.** Don't choose natural stone that does not have a track record of performance and availability in the local climate. Inappropriate stone selections can lead to substantial repaving costs over the lifecycle of the building.

Site/Landscape

LESSON 3. LANDSCAPING AND IRRIGATION, INTERIOR AND EXTERIOR

Site landscaping and irrigation can vary widely with geographic region, facility mission, and site context. Typically, however, successful installations require minimal maintenance.

When selecting and designing landscaping:

- **Select appropriate plants.** Inappropriate landscaping can cause long-term maintenance and replacement expenses. Outside, select plantings that are appropriate for the region and for the building site. Consider anticipated heat island effects and glare from the buildings. Inside, environmental conditions (including heat and relative humidity) along with possible allergens should be considered with design of interior landscaping in order to eliminate excessive replanting and landscaping maintenance costs.



Heat island effects can kill interior planting.

operational, maintenance and repair expenses. Consider ways to eliminate the need for an irrigation system, for example, by using xeriscaping.

- **Account for maintenance.** Consider water demands and maintenance requirements such as trimming and weeding. Also consider the durability of plants to foot traffic, particularly at urban sites where protests or social gatherings may occur.
- **Plan ahead.** Design landscaping based on the size of plantings at maturity to avoid premature replacement or severe pruning.
- **Consider indoor environmental effects.** Consider potential impacts of indoor irrigation on relative humidity, allergens, and potential for microbial growth.
- **Keep it simple.** If not designed, installed, and commissioned correctly, irrigation systems can cause long-term

- **Consider implications of gray water.** If using gray water for irrigation, consider the sensitivity level of plantings, as well as any effects of potential contamination or pollution of the landscaping.

AVOID:

- **Choosing high-maintenance plantings.** Don't choose lawns or other high maintenance ground covers. Also avoid highly sculpted plants and hedges that require frequent maintenance and are prone to damage.



- **Blocking the flow.** Don't choose landscaping that can adversely impact pedestrian traffic flow at entrances and critical circulation points.

- **Compromising security.** Don't choose plantings that affect security by providing concealment opportunities or limiting visibility of security personnel.

- **Allowing mulch to migrate.** Make sure that mulch is contained to its designated area to avoid its washing onto sidewalks or into drains.

ing planting.

Envelope/Structure

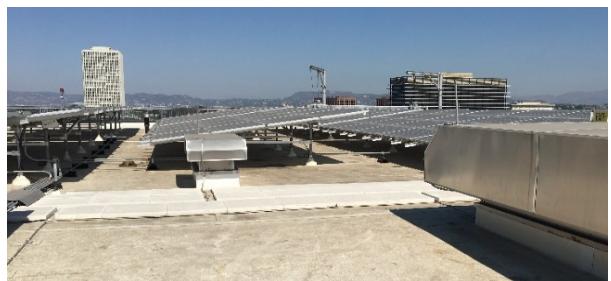
LESSON 4. EXTERIOR WINDOWS/FACADE

A public building's enclosure determines its impression within the community, impacts energy usage, and directly affects the comfort of occupants and visitors. It is essential that building enclosures be designed for their aesthetics as well as for serviceability and future maintenance needs.

When designing the building enclosure,

DO:

- **Consider façade cleanability and maintenance up front.** Consideration of the impact of enclosure complexity should lead to successful harmony among aesthetics, shading, and cleaning concerns.
- **Consider the effects of shading devices on the building.** Exterior sunshades need particular scrutiny, as they can generate wind noise and complicate cleaning and other exterior wall maintenance. Architectural vertical extensions and cantilevered “fly-bys” designed to hide air intakes can cause air recirculation and entrapment, allowing odors to be drawn back into the building. (Similarly, solar photovoltaic arrays can trap and channel sewer gases from roof plumbing vents over long distances to air intakes.)



Vents below these PV panels released odors that were recaptured by curtain wall extensions and induced into the outside air intakes. Carbon cartridge “Odor Hogs” were installed at the vent terminals to control the odor.

- **Include the infrastructure.** Incorporate infrastructure (engineered roof anchors, safety line tie-backs, window-washing equipment, etc.) at the roof for more intensive facade maintenance, such as sealant replacement or glazing replacement that involves swing stages or lifts, into the enclosure design process.

- **Evaluate color and texture.** The color and texture of façade materials should be evaluated in the local environment for cleaning demands. Light-colored buildings in urban environments may require more frequent cleaning.



Rundown staining caused by rusting steel.

- **Anticipate rundown staining.** Evaluate the potential for staining facade elements, adjacent systems, or objects at grade due to water rundown staining or component corrosion.

- **Weigh the use of ledges and recesses.** Ledges, niches, and other recesses should be avoided or at least their depth and slope should be critically evaluated due to their propensity for staining from water run down, and bird roosting.

- **Consider making parts of the façade removable.** For veneer cladding systems, consider requiring that the façade be removable in discrete segments or regions to access and repair the weather-resistive barrier (WRB) system without extensive façade disassembly.

- **Consider specialty glass types.** Due to the risk for glass breakage, consider the

use of laminated, heat-strengthened safety glass where possible and minimize tempered glass use in general. Where UV damage is of concern (e.g. fading of millwork in courtrooms, rooms with artwork or display cases), consider the use of laminated glazing, which can be designed to reduce UV transmission. Ballistic glazing units have a propensity to crack and delaminate when exposed to direct sunlight for extended periods of time due to uneven heating. Installations should consider the use of shading to minimize these conditions.

AVOID:

- **Designing non-redundant enclosure systems.** Don't design non-redundant enclosure systems that do not include a drainage layer and rely solely on exterior layer integrity for air- and water-tightness.
- **Encouraging streaks.** Don't choose highly polished exterior surfaces that can streak or spot and are otherwise difficult to keep clean.
- **Inviting feathered friends.** Don't create inviting places on the facade for birds to nest.

Envelope/Structure

LESSON 5. CANOPIES

Canopies provide useful shade and shelter from the elements; however, they may conflict with functionality and potentially increase maintenance.

Canopy designs should consider the following:

- **Keep it simple.** Avoid complex materials and assemblies as well as corrosion-prone materials. Recognize the extreme exposure requirements for the canopy materials and assemblies (such as excessive heat, snow load, wind uplift, etc.).



The low slope on this canopy does not permit rain to clean the glass adequately. Below, a new laminated glass unit has cracked.

- **Anticipate drips.** Review drip lines and patterns to avoid slip risks and rundown staining.
- **Plan for access.** Consider means of access to the canopies for repairs and maintenance. As non-critical elements, it should be understood that they will receive minimal preventive maintenance or attention until a severe problem occurs.

- **Assure QA/QC procedures are in place.** Laminated glass units in canopies that appear cracked, fogged or even with fingerprinted on the inside of the laminate may be the result of poor quality control during manufacture. The cause of these failures should be investigated, but the presence of the visible “contamination” of the interior glass surfaces suggests poor quality control during manufacture.



AVOID:

- **Proprietary specifications.** Product availability and manufacturer reliability in the local market should be considered as part of the procurement process, greatly reducing increased replacement costs. Custom-designed and -installed building

entry canopies can become a source of major repair/replacement costs.

Envelope/Structure

LESSON 6. ROOFING

To prolong roof service life:

DO:

- **Coordinate roof design.** Improper roof design, material selection, and construction can cause significant leaks resulting in long-term maintenance and repair costs and mission disruption.
- **Provide dedicated access.** Make all roof areas accessible for inspection and periodic maintenance, which is critical to address problems early. Install walking pads for maintenance traffic to roof top equipment, and install tie-backs for fall protection. Make sure that equipment is away from the edge of the roof.
- **Consider the supporting elements.** When installing equipment, such as solar panel arrays on roofs, design the supporting elements to minimize penetrations into the roof and maximize the space between them and roof surface to facilitate replacement. Minimize pitch pockets. Consider choosing a smooth surface to allow access for rolling tool carts.
- **Commission right.** Provide proper and documented envelope commission for the roof including the enforcement of electronic leak detection requirements during commissioning to identify deficiencies in the membrane that can be corrected prior to building occupancy.
- **Consider snow removal from the roof.** Make provisions for how and to where rooftop snow can be removed without damaging pedestrians, landscaping or surfaces below.



Avoid penning rooftop equipment and limiting access for maintenance.

Envelope/Structure

LESSON 7. LOADING DOCKS AND MAIL ROOMS

A properly designed loading dock allows smooth transition of materials to and from the building and is essential to facility maintenance, tenant satisfaction, and efficient operations of all tenant agencies.



The recycling dumpster obscures the view from the security screening area to the loading dock entry

DO:

- **Secure access.** In no case should unscreened vehicles or pedestrians be afforded access to loading docks and areas.
- **Consider acoustics.** Take into account acoustic requirements for any building program located adjacent to or above the loading dock.
- **Plan for big equipment.** Provide enough space for security personnel and security screening equipment, including a security booth, magneto-meter, and x-ray scanner for packages.
- **Provide a clear line of sight.** Maintain a clear line of sight between

the security area and the loading dock entrance, as well as to ancillary equipment, such as dumpsters and compactors.

- **Opt for optimal turning room for vehicles.** Above minimal requirements, consider providing clear space for turning radii. Additional space for maneuvering vehicles substantially reduces delivery and departure times, improves operations in enclosed loading docks, and reduces the risk of accidents.
- **Provide restrooms for drivers.** Restrooms within the loading dock but outside the facility's secure perimeter, permits drivers to use restrooms without the need to pass through security screening. This can speed up delivery and departure schedules substantially and improve loading dock efficiency.
- **Design to accommodate efficient and secure mail screening.** Provide a security screening area immediately accessible to the mailroom that allows x-ray of large packages. (Unscreened mail should never enter the public portions of the facility.) The mail room should accommodate glove boxes and ventilated hoods for handling suspicious packages as well as space for carts to pass one another to reduce the likelihood that a cart ready for deliveries will be trapped by another parked cart.
- **Include emergency showers.** Near the screening area, provide emergency showers/eyewash stations that include a floor drain and seamless floor finish. Drainage may also require containment for preventing suspect hazardous materials from entering into mainstream utility lines.

AVOID:

- **Encouraging excess noise.** Don't locate the loading dock next to acoustically sensitive activities.

Envelope/Structure

LESSON 8. GARAGES AND PARKING

Shortcomings with parking and garages can be observed in nearly all of the facilities. Provide convenient and safe parking within prospectus limits.



The double-wide garage door has malfunctioned several times, and because its replacement parts are not a standard order, delays can be long and costly.

DO:

- **Provide enough, easily accessible parking.** Realistic accommodation for visitor parking within the allowable limits should be included. Visitor parking should be located with consideration for ease of wayfinding to the main entrance of the facility.
- **Design for full occupancy.** In facilities that require secure parking, accommodations should be provided for the secure parking requirement at full occupancy of the tenants within allowable prospectus limits.
- **Size for clearance.** Garage doors and guard booth canopies must be sized to accommodate vehicle clearance. Consider height, width, and turning radius for trucks, busses, and large utility vehicles (waste disposal, mail, package deliveries, movers, etc.)
- **Provide bike access and storage.** Consider providing access for bicycles and a bicycle rack within the garage to offer security and weather protection. Consider access, screening, and location of restrooms, showers, and changing rooms to the bicycle rack amenities.

AVOID:

- **Using proprietary specifications.** To greatly reduce replacement costs, product availability and manufacturer reliability in the local market should be considered as part of the procurement process.
- **Designing custom garage doors.** Nonstandard sizes, custom designs, or other issues affect replacement part availability. When a door goes out of service due to unscheduled maintenance, it can directly impact operations and security of a facility, especially if replacement parts or service technicians are not readily available.

Architecture/Interiors

LESSON 9. INTERIOR FINISHES

Selection of appropriate interior finishes for a government building is key to its aesthetic success, the quality of its workplace, and its ability to project a positive impression of the federal government. To enhance these positive conditions, consider durability and ease of maintenance carefully when selecting all interior finishes.



The white door finish highlights dirty hand prints.

DO:

- **Consider neutral carpet colors.** Light-colored carpet or carpet with a regular geometric pattern shows stains easily and is challenging to maintain. Give preference to darker, neutral colors and irregular patterns that conceal incidental stains, particularly in high-traffic areas.

- **Use larger tiles on floors and walls.** The use of large tiles, especially in restrooms, reduces grout joints, which are difficult to keep clean.

- **Design to avoid glare.** In entrance lobbies and public spaces that use natural light, especially where security cameras are required, recognize the potential for glare from reflective floor finishes such as polished stone and terrazzo. Note also that excessive glare can make security camera images difficult to read and can present a hazard for people with vision impairments.

- **Use tested floor materials.** Select materials with a proven track record for durability and maintenance, and steer away from unusual or untested flooring materials.

- **Specify satin or eggshell paint finishes.** In high-traffic areas, select satin or eggshell finishes for ease of maintenance. Flat paint finishes are challenging to maintain.
- **Provide corner guards.** Corner guard protection should always be provided in any space where delivery carts, movable furniture, dollies, or other equipment could scuff or damage walls.

AVOID:

Installing finishes in an unconditioned space. Provide temporary humidity and temperature control for millwork areas during construction and climatization of building HVAC. Millwork can be permanently damaged by uncontrolled humidity.

- **Choosing light color finishes.** Avoid floor tiles with numerous grout joints (especially with white or light-colored grout) as well as painted floors in areas of high pedestrian traffic or wet locations.
- **Specifying unique, specialty wall finishes.** As with floor finishes, the selection of unusual or untested wall finish materials should be avoided. Choose only materials with a proven track record for durability maintainability, and continued availability.
- **Using oversized acoustic ceiling tiles.** Systems with tiles larger than 2-feet by 4-feet are



difficult to handle for above-ceiling access, and a supply of replacement materials is more difficult to guarantee for the life of a facility.

Storing millwork in unconditioned spaces can result in warping and cracking.

Architecture/Interiors

LESSON 10. ATRIUMS AND LOBBY SPACES

The aesthetic value and sense of identity created by atriums and public spaces can be an expression of the building's mission and merit additional costs in design, construction, and maintenance; however, it is important to understand the O&M requirements to maintain these building features.



The top of the atrium guardrail is low enough to invite setting down objects that could fall over the edge.

When designing atriums and expansive lobby spaces:

DO:

- **Consider equipment needed.** As part of the overall design, consider equipment and details required to access high ceilings, upper portions of walls, and sculptures for cleaning and maintenance. Include consideration of clearances to walls and fixed installations (benches, furniture, etc.), clearances at doors, floor loading, and the specifications of readily available equipment. Note also that this in-house equipment will require dedicated storage areas.
- **Reduce heat gain and glare.** Where possible, reduce heat gain and glare with window treatments, fenestration, or well-designed external shading.
- **Consider plumbing placements.** Plumbing, including supplies for fire protection systems, should not be located near or in exterior walls or unheated plenum spaces in cold climates.
- **Simplify circulation and wayfinding.** When employing a large central atrium, carefully consider the location of the vertical circulation and restrooms or consider placing them in more than one location. Present clear, familiar, and recognizable destinations from the entry lobby that carefully consider arrival and departure paths. Inadequate and ineffective circulation patterns can decrease occupant and visitor satisfaction as well as reduce the efficiency of the facility mission.
- **Standardize signage design.** Custom design signage requires specialized replacement of room and name signage at occupant changeover.
- **Consider users with low vision.** Stairs with no tread delineation and translucent floor panels, with or without uprights, provide particular challenges.

- **Always remember safety concerns.** Safety concerns can increase the time and costs to alleviate a hazard in addition to dramatically increasing liability. For instance, some atrium guardrails are placed low enough to tempt children to climb and people to set down drinks, phones, and heavy boxes, even though the ledge cants inward to discourage seating.

AVOID:

- **Relying on unique equipment.** Avoid the need for unique or custom-built access equipment that cannot be readily acquired or rented, or that may require specialized maintenance.
- **Choosing shades with hard-to-reach motors.** Don't use mechanical or operable shades that will require motor maintenance at elevated or difficult-to-reach locations, or that are prone to breakage.

Architecture/Interiors

LESSON 11. STORAGE

The long-term success of any facility depends on diligent implementation of a thorough operations and maintenance program, and one of the keys to the long-term success for operations and maintenance is providing sufficient area in the building to efficiently store spare materials, replacement parts, and the equipment that is necessary to keep the building functioning with optimal efficiency. When buildings fail to accommodate these storage requirements adequately, makeshift storage areas pop up in spaces intended for other functions, most frequently mechanical and electrical rooms. In these instances, the stored materials quickly can become a hindrance to equipment access, a fire hazard, and a potential obstacle to safe egress.



The many neatly stacked boxes should have been anticipated in storage design, to avoid storing in the corridor.

DO:

- **Consider storage needs early.** Develop an equipment list as early as possible in the planning and programming stages of the project, and dedicate space in the O&M and janitorial storage areas for storing the equipment. Anticipate and dedicate storage requirements for maintenance materials (such as light bulbs, air filters, equipment belts, etc.), the total amount of attic stock material called for by the specifications (such as ceiling tiles and carpet), and dedicated space for oversized equipment such as lifts and ladders.



This penthouse offers generous room for equipment and filter storage.

- **Include a work space.** O&M staff need a small work space for a Building Automation System (BAS) work station, a work bench, tools and equipment, and O&M manuals.
- **Consider adjacencies.** The O&M storage space should be easily accessible from a large freight elevator. The location should consider minimizing the acoustic impact for adjacent spaces. The location should discourage the potential for the O&M storage area to be annexed for a different programmatic function.
- **Right-size elevators.** Use the equipment list for sizing freight elevators.
- **Plan the paths.** Consider routes and the clear paths for all equipment for the entire facility in the planning process. Selection of finishes, especially floor finishes, should also take the planned routes for heavy equipment into account.
- **Dedicate space.** A single, large, dedicated space is preferable to distributed storage closets (in addition to janitorial closets).
- **Include shelving.** The layout for the O&M storage should be able to accommodate standard shelving units in a manner that maximizes both linear feet of shelving and ease of access.
- **Storage has limits.** Provide signage regarding load capacity of structural floor framing so the structure is not overloaded by accident. The sign should state the rated capacity of the floor and instruct the property manager to consult with the GSA Regional Structural Engineer for guidance.



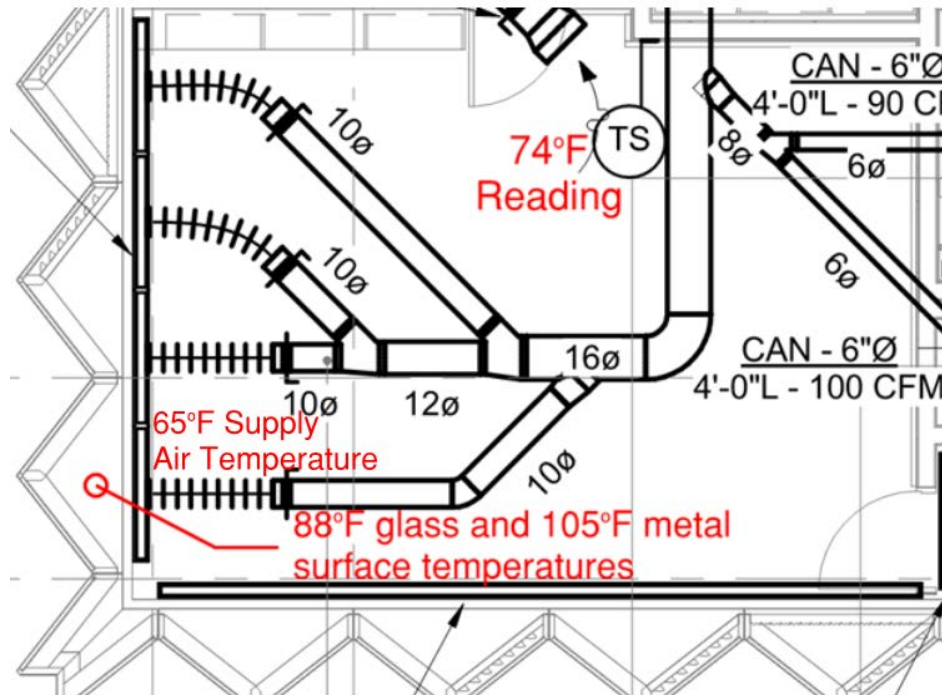
AVOID:

- **Overlooking space requirements for the big stuff.** Don't forget storage space requirements for lifts, scaffolds, and bulky equipment such as floor buffers.
- **Designating off-site storage.** Don't designate storage for materials off site, even in an adjacent facility.

Include shelving in storage areas.

Mechanical/Plumbing

LESSON 12. OCCUPANT ENVIRONMENTAL CONTROLS



Rooms can feel uncomfortably warm when window pockets trap solar energy.

Occupants' satisfaction with their work environment results from a combination of

- Psychological mood
- Lighting quality and views
- Acoustics
- Personal metabolic rate and clothing worn
- Temperature, humidity, and speed of the air
- Temperatures of the surrounding surfaces (walls, ceiling, floor, windows, and skylights) in sight of the occupant.

Increased levels of dissatisfaction occur with undesirable air movement, which in turn leads to a dissatisfaction with the inability to directly control their space air temperature with a thermostat. Dissatisfaction in air movement is found both from drafts and stagnant conditions. Sometimes in a facility, both occupants and facilities staff are unaware that the air distribution pattern from their supply air devices is manually adjustable. Additionally, occupants close to large areas of glass are more sensitive to air temperatures than those without the radiant exposure to the highly variable hot-to-cold surfaces. Buildings with less glass generally have higher thermal satisfaction ratings. It has been demonstrated that controlled cooling surfaces overhead (e.g. a passive chilled beam panel), result in occupants who are more tolerant of higher air temperatures and are more accepting of the open floorplan thermostat zoning.

DO:

- **Allow users to adjust the air.** Allow occupants (or maintenance staff) to adjust all supply air system patterns. Just knowing that the airflow pattern is adjustable provides an element of control to occupants (even if maintenance staff has to do the work) and raises satisfaction levels.
- **Design for individual controls.** Design radiation systems to be controllable by individual spaces, and not by entire building façade. Without independent space control, higher levels of dissatisfaction occur with baseboard radiators.
- **Let staff teach the occupants.** Give facilities staff simple means with which to educate occupants of the options available for customizing working environments.
- **Control solar radiation.** Design building enclosures to allow control of solar radiation onto occupants' and perimeter spaces.
- **Control surface temperatures.** The building enclosure needs to demonstrate control of heat gains and losses on surfaces in the perimeter zone. Stabilize material surface temperatures to closely match the desired air temperature. Give special attention to window interior surfaces, metal panels, skylights, medium- and dark -colored flooring, and horizontal surfaces below skylights.

Mechanical/Plumbing

LESSON 13. ATRIUM/LOBBY PRESSURIZATION

Tall buildings, and particularly those with multistory atriums that include security screening operations and direct connections to the outdoors, tend to struggle with pressurization control at their main entries. Building control systems attempt to limit unnecessary energy consumption, local discomfort, air quality reductions, and security risks (doors not latching closed) from uncontrolled pressurization. Pressurization control works together with humidity control, and both excessive infiltration of outdoor air and exfiltration of treated indoor air wastes energy and water resources. Recurring issues include exposure to highly variable winds across building openings, and temperature differentials between the indoor and outdoor spaces, and the ground and roof levels.

- **Address differential pressurization.** Design vestibules and door assemblies to address differential pressurization throughout the daily cycles (including early morning and late evening arrivals and departures). Consider energy losses due to thermal and air leakage at entry points, primarily by avoiding operable systems that do not minimize or regulate air transfer from exterior to interior. A properly proportioned entry vestibule or revolving doors can virtually eliminate unwanted air transfer.



- **Control atrium/lobby pressurization.** Inappropriate lobby/atrium design can result in building pressurization problems that can be expensive to monitor, adjust, and maintain. One project experiences unnecessary energy consumption from uncontrolled pressurization. Airflow across its main entrance alcove creates a negative pressure differential that prevents the doors from fully closing and locking, especially during high wind events, creating a significant security concern. Pressurization control works together with humidity control, and both excessive infiltration of outdoor air or exfiltration of treated indoor air wastes energy and water resources. Provide effective pressure monitoring across the desired barriers, specifically at the ground level. Additionally, monitor each level's lobby area against readings at both the ground level and the top level.
- **Consider revolving doors for atriums, lobbies and vestibules.** Where double-door vestibules are provided, users often open both doors during high traffic periods. Consider high-capacity revolving doors to mitigate these issues.

- **Consider vestibules, even for smaller buildings.** In buildings without vestibules, extra attention and adjustments to both air systems and door hardware were found to be ongoing activities even after years of operation. For all buildings, architectural compartmentalization (separate spaces) at exterior doors and active pressure control measuring across each building exterior door would enhance the reliability of pressurization control, and reduce commissioning and retuning efforts.

Mechanical/Plumbing

LESSON 14. SYSTEM/BAS OPTIMIZATION.

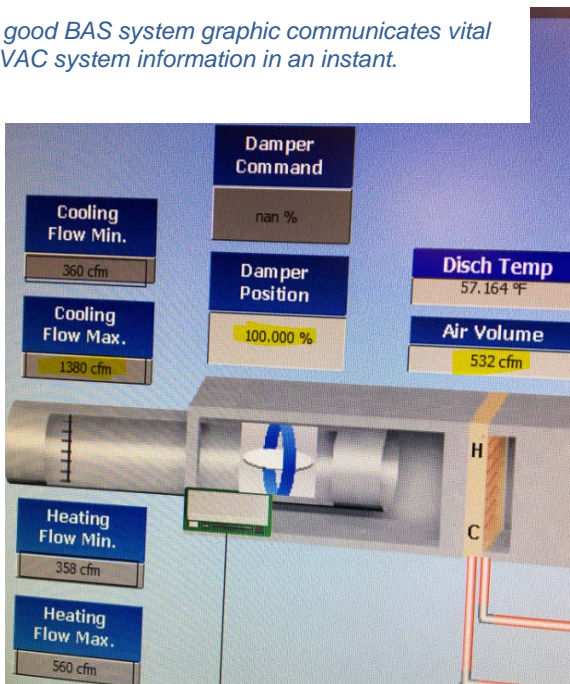
Buildings today need a variety of operating modes to achieve their energy performance goals. At the same time, buildings also need to provide for the workspace needs and high satisfaction of their occupants. These sometimes conflicting goals place a high demand on matching HVAC system designs to the occupancies, and corresponding ideal placement and responsiveness of sensors within the spaces and critical points of the systems, all creating a trend toward complex controls programming. Optimization of the controls becomes a continuing task years after occupancy.

To decrease the optimization period and streamline operations:

DO:

- **Keep it simple.** Refine designs and control modes to the simplest baseline.
- **Keep it consistent.** In the United States, provide control systems that include English inch-pound (IP) values from top to bottom.

A good BAS system graphic communicates vital HVAC system information in an instant.



- **Optimize the BAS.** The BAS can substantially reduce energy efficiency if optimized to integrate the various building systems for high performance.

- **Commission for a year.** Extend commissioning tasks for a full calendar year, extending into occupancy, to demonstrate and record setpoints necessary for all operating modes accommodating all seasons. Provide a simple, bulleted list detailing the sequence of operations, which can be used for sequence of operations verification.

- **Educate the operators.** Simplified systems encourage proper and more complete training of operators, and put an ultimate goal of delivering

consistent building performance year-after-year within reach. Operator training should cover all aspects that affect equipment reliability and longevity, as well as setpoints, operating patterns, and schedules for occupant comfort.

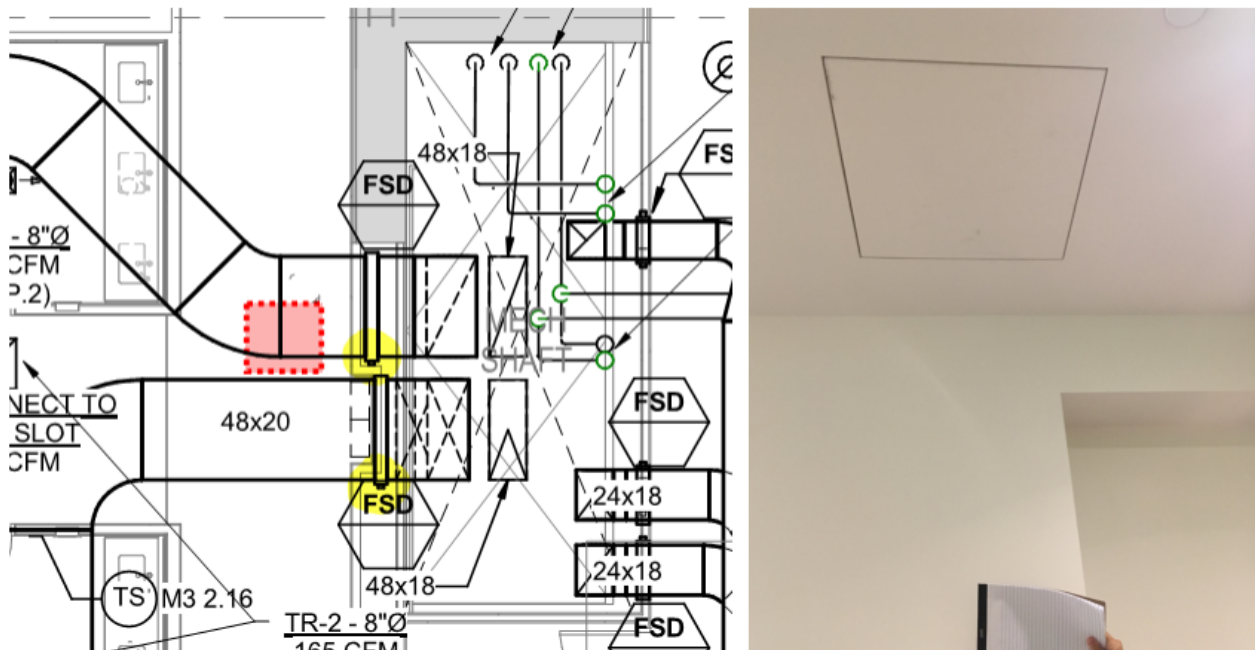
- **Fine-tune and document training times.** During transition of operations staff, determine and document the appropriate training program and the time required for new operators to learn the course of activities.
- **Provide more robust systems and equipment to reduce long-term maintenance costs.** These systems, if comparably energy efficient, will yield the lowest total cost of ownership. Consider normal and peak operating points, so that motors are not driven into their service

factor tolerances to meet loads. Design operating sequences with staging of similar equipment to provide both efficient operation and points that do not unnecessarily stress the equipment.

Mechanical/Plumbing

LESSON 15. ACCESSIBILITY FOR EQUIPMENT MAINTENANCE/REPLACEMENT/REMOVAL

To achieve maximum utility and life of installed equipment and increase total value through reductions in maintenance task labor, provide: unobstructed clearances, access to those clearance spaces, the prompt availability and convenient location of spare parts, and provisions to expedite inspections.



Repairs to this damaged fire-smoke damper were hampered by inadequate access above the hard ceiling as well as its tight placement between two ducts.

DO:

- **Plan ahead.** Plan for maintenance, operations, workshops, and proximities of spare parts storage early in the programming and design phases of a project.
- **Know the O&M staff's capabilities.** Understand the current and potential maintenance capabilities of staff. Locality plays an important role, as remote locations may need a simpler approach to maintenance. This is essential to designing a system that will meet the performance goals of the project in both the short- and long-term.
- **Loop management in.** Inform the property management team of maintenance and operations implications, as well as service-enhancing and labor-reducing features during exploration of design alternatives.

- **Consider system complexity.** When current maintenance and operations capabilities (including access to unique tools, such as welding stations or manlifts) are inadequate for a given design alternative, select a simplified design alternative to avoid the need entirely, or explore strategies for enhancing capabilities through the selection of higher expertise contractors who can demonstrate a lower Total Life Cycle Cost.



Avoid single leaf doors for areas that need equipment delivery and removal.

- **Provide access for immediate operational adjustments.** Means of automating monitoring and enabling remote operation, such as intuitively via the building automation systems (BAS), should be the first consideration. Recognize the added burdens and maintenance costs of locating controls and distribution devices in places with difficult access or where normal schedules of users need to be interrupted.

- **Know schedules.** Know building operation schedules that indicate when equipment can be taken off-line for service. For spaces that operate 24/7, consider redundant, standby, or temporary connections to avoid loss of service or unexpected costs. Additionally, to reduce maintenance costs, either locate components requiring planned maintenance outside of restricted spaces (such as holding cells) or provide an alternate means of access that

does not compromise restricted zones.

- **Minimize periodic maintenance operations.** During design, look for opportunities to reduce the maintenance burden by minimizing periodic maintenance operations. For instance, using direct-drive fans in lieu of belt-driven fans would eliminate periodic belt inspections, period belt replacements, and unplanned service outages caused by belt failure. A second example for new construction or retrofits would be specifying hardwired sensors for plumbing faucets and flush valves in lieu of battery-operated devices to reduce maintenance and increase the level of service provided to occupants.
- **Incorporate access provisions to minimize maintenance task durations.** These provisions include locating spare parts storage in locations convenient to the points of use, as well as providing stairs, doors, hatches, lifts and hoists of satisfactory capacity and location to allow for maintenance activities.
- **Plan for equipment maintenance/replacement/removal accessibility.** Small openings, such as single-leaf doors, can generate significant replacement time and costs. Use double-leaf doors to facilitate delivery and removal of equipment such as air-handling units. Also plan

travel paths. Additionally, avoid locating equipment in hard-to-reach spaces, which require significant time to maintain and make it difficult to respond to emergencies. If air-handling units are roof-mounted, make sure they are not too tightly penned in; i.e., have adequate coil pull space.

- **Plan access for end-of-useful-life replacement.** Plan for the replacement or upgrading of the prime mover equipment for mechanical, electrical, and plumbing systems to occur several times over the life of the facility. As such, the means of replacement should be inherently obvious and not require imagining dismantling and reconstruction of building components such as walls, floors, and roofs, or protecting less durable or highly valuable features.



VAV boxes directly above the Air Handling Units allow for easy access for maintenance.

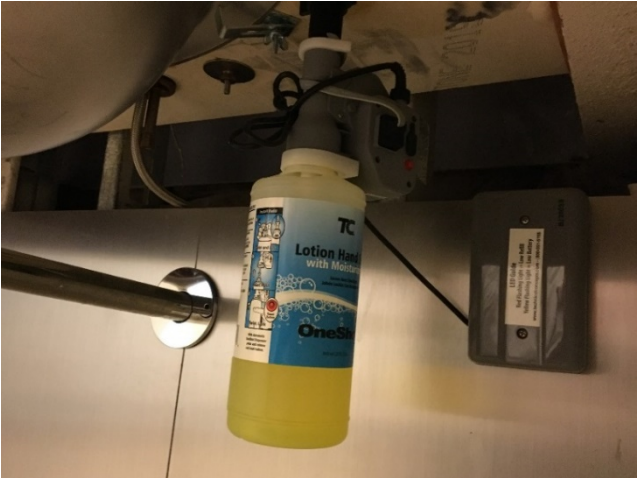
AVOID:

- **Placing equipment in hard-to-reach spaces.** Suspended equipment, concealed equipment, equipment in occupied spaces, equipment located outdoors, and equipment housed in confined or below-grade spaces--are all likely to experience neglect, reduced performance, and potentially shortened service lives.

Mechanical/Plumbing

LESSON 16. PLUMBING BIBBS AND RESTROOM FEATURES

When a project has too few or poorly placed water hose bibbs for custodial use, custodial staff need to couple multiple hose sections (often three lengths) together to reach routine work areas, both inside and outside the building. This can include rooftops as well as site hardscape and landscape areas. In addition, it is possible that there are locations where the hoses must be strung through secure doorways to reach the service points of use. When this occurs, those doors are kept open and unlocked. The staff are also short on space to store the numerous hoses, so try to keep the maximum distance from a hose bibb to the use point to within 100 feet (the length of one hose).



Avoid maintenance intense, battery-operated fixtures.

DO:

- **Carefully consider number and placement of hose bibbs.** Provide a generous number of hose bibbs on rooftops and in interior and exterior landscaped and hardscaped areas, including the garage and loading dock.

Use hard-wired or manual fixtures in restrooms. Battery operated fixtures, including automatic sinks, soap dispensers, and paper towel dispensers are difficult to

maintain. Not all batteries fail at the same time, and access to under-counter locations is time consuming. Provide a hard-wired connection for any sensor-operated restroom fixtures.

Lighting/Electrical

LESSON 17. DAYLIGHTING AND SHADES

With the extensive and much appreciated increased access to daylighting, the importance of shades is paramount for providing a comfortable daylit scenario of which occupants approve. Shades must be designed in coordination with the building construction, as they are as much of the overall daylighting strategy as the size of the windows or external, fixed shades.



Glare can create concerns, even through shades.

For optimal use of shades:

DO:

- **Integrate shade design into the design process.** Consider shade design as part of the overall lighting strategy and exterior building appearance.
- **Design shades to fit each window.** Require the shade manufacturer to send a representative to visit the building as it is nearing completion to obtain accurate in-field measurements of each shade required.
- **Mix and match.** Consider a strategy that includes a mix of manual and electronic shading.
- **Optimize shades.** Tie automated shades into the building control system or lighting control system.

- **Automate shades opening.** Program the system to automatically open the shades every morning and allow for users to adjust the shades as needed.
- **Shade skylights.** Consider shades for skylights.
- **Consider maintenance accessibility of interior shading.** Make sure that interior shading devices are easy to service or replace. Restricted access requires significant time and expertise in replacing or repairing the shades, adding to the overall operations costs.

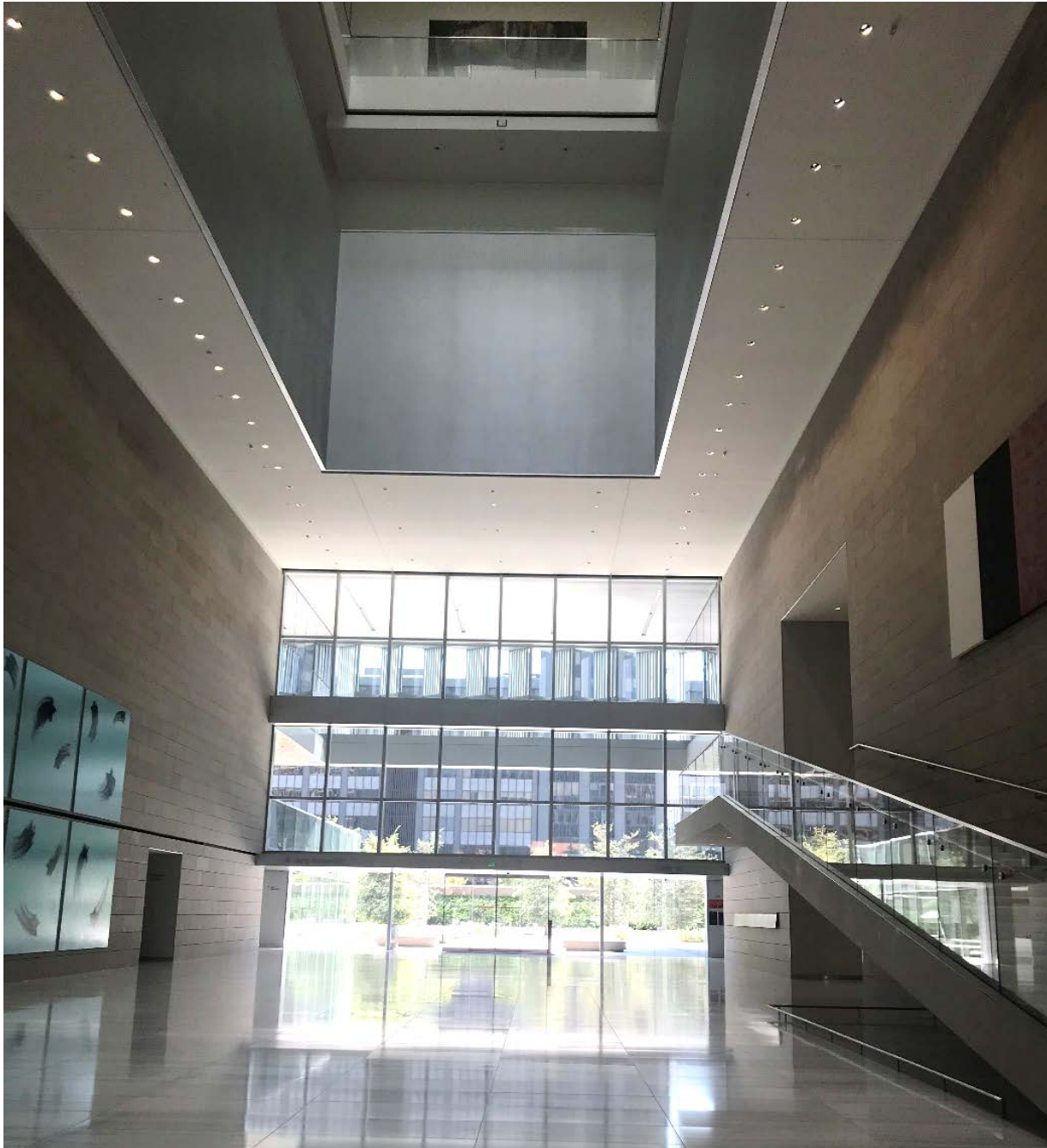
AVOID:

- **Placing desks under unshaded skylights.** Don't locate workstations underneath skylights without employing a shading system.
- **Requiring tenants to install their own shades.** Make shading design part of the design process.
- **Specifying ill-fitting shades.** The intent is to avoid ill-fitting shades that are not effective. Odd shapes should be avoided, along with extremely long windows that require excessively heavy shades. Additionally, avoid tucking the shade pocket where it is difficult to access for maintenance.

Lighting/Electrical

LESSON 18 LUMINAIRES AND LIGHTING EQUIPMENT

All lighting equipment will need repair at some point in its life. And note that while LED luminaires ensure that required access will be less frequent than for fluorescent or legacy light source equivalents, access to lighting still will be necessary throughout the lifetime of the building.



Lighting in this atrium may be difficult to access for maintenance, particularly over the stairs.

DO:

- **Keep luminaires within easy reach.** Avoid luminaires located in high ceilings, especially in atrium spaces. These prove difficult or impossible to clean and re-lamp. The result is that many lights are never used or remain permanently broken. If a lift is required to maintain luminaires, it may necessitate robust floor protection before it can be used, potentially adding significant O&M labor time and costs.
- **Review all Ingress Protection (IP) ratings for all luminaires.** This is particularly important for luminaires in kitchens, showers, restrooms, back-of-house spaces, and exterior environments. Exterior in-grade luminaires often see moisture penetration and are notorious for early failure. Lighting designers and electrical engineer should work together in projects where the electrical engineer specifies luminaires for back-of-house spaces.
- **Consider shading for luminaires.** Excess heat greatly impacts the life of luminaires, especially LED luminaires, and daylight can cause excessive heat gains that will affect a luminaire's lifespan. Consider shading systems can also extend the life of luminaires by reducing direct sunlight exposure.
- **Consider access when selecting lighting equipment.** O&M staff must also be able to access the components *within* the luminaire. Consider both aperture size and disconnect locations of drivers, ballasts, and light sources.
- **Standardize lamps/ballasts.** The lack of lamp/ballast standardization in a building can increase O&M times and costs, as well as increase storage
- **Use reputable manufacturers that engineer quality products.** Review industry standard test data for projected life of light source, driver, and/or ballast. Use mock-ups for evaluations.

AVOID:

- **Mounting luminaires above louvers.** Mounting luminaires above louvers increases recurring labor costs, as one or more louvers must be removed to replace a lamp.
- **Neglecting consideration of “obstacles” to lighting O&M.** Maintenance obstacles such as security screening equipment and staircases are easily overlooked in maintenance accessibility discussions.

Lighting/Electrical

LESSON 19. LIGHTING OPTIMIZATION AND CONTROL

Energy efficiency goals have steered designers and engineers toward designing for overall lower light levels in workspaces with supplemental task and personalized lighting. Additionally, relying on daylight with its variable light levels may increase the need for task lighting. Allowing occupants to control some, if not all, of the lighting in their space results in higher user satisfaction. In areas with reduced light levels, consider building-provided task lighting by default to increase overall satisfaction.



Bright white walls and ample daylight negate the need for the downlights to be on. The lighting control system has not yet been integrated with the BAS.

DO:

- **Optimize lighting.** Balancing and optimizing lighting can improve energy efficiency and occupant satisfaction, especially in open offices. Users near the windows and directly under skylights can have too much light, while furniture and shelving can block adequate light from overhead luminaires from reaching others' desk surfaces.
- **Provide task lighting.** Provide task lighting to all occupants, especially those working in an open office with no control over the ambient lighting.
- **Take control.** Provide localized vacancy or occupancy sensors on task lighting in each work space or provide a controlled outlet to

power the task lighting.

- **Keep up with training.** Schedule training with the controls system manufacturer whenever there is a change in operations maintenance staff or control systems' software update. Do not assume that there is sufficient information regarding the lighting control system to be passed along when O&M staff changes.
- **Plan regular maintenance.** If control system manufacturer does not offer a continuous service contract, implement a plan to ensure the lighting control system receives repetitive maintenance from knowledgeable staff, and that the system receives any software updates upon availability.

- **Keep up with energy savings.** To improve the functionality of the lighting control system: regularly update the lighting control system software; train operations personnel on how to optimize and set the lighting control levels and features; and educate tenants on their personalized lighting control systems.
- **Make lighting controls compatible with luminaires.** If the systems are not compatible, lighting will likely flicker, especially when dimmed. This is especially prevalent with phase dimming technology, such as Magnetic Low Voltage (MLV), Electronic Low Voltage (ELV), forward-phase, and reverse-phase. LED retrofit lamps are the biggest offenders.
- **Commission and recommission.** Schedule training with the controls system manufacturer whenever there is a change in operations maintenance staff or control systems' software update. Implement a plan to ensure the lighting control system receives repetitive maintenance from knowledgeable staff, and that the system receives any software updates upon availability. Recommission the lighting control system at least once within five years of the initial commissioning.
- **Coordinate the lighting equipment, electrical system, and control system.** Forcing a luminaire to operate outside of its tested parameters will strain the electrical components and light source, resulting in early failure.

AVOID:

- **Assuming that the lighting control system won't change.** Changes in furniture placement, space function change, and surface color will affect the operation of the control system and may trigger the need for recommissioning.
- **Affecting security by glare.** Don't create direct or reflected glare, especially in courtrooms, entry guard stations, headhouses, and other areas concerned with security. Where reflective or glossy finishes are specified, check camera locations with light modeling to better assure images will be readable.

Lighting/Electrical

LESSON 20. ELECTRICAL PLACEMENT AND LABELING

Plan upfront so that electrical systems are well located and distributed for robustness and ease of maintenance, and well marked for clarity of operation.



DO:

- **Complete circuit designation and marking.** System and component marking can dramatically reduce O&M time and repair expenses. When a breaker trips, the affected area has to be determined. Also, identifying which breaker feeds an area is very difficult and extremely time consuming.
- **Label all equipment.** Provide extensive labeling for all electrical equipment and electrical rooms, including a mimic bus located near the main switchgear.
- **Take the high road.** Ensure that electrical equipment is elevated above potential water sources so that they drain by gravity and avoid flood risk, including from failed piping, sumps and pumps.
- **Be generous with outlets.** Provide plenty of electrical receptacles in areas with high use, such as break areas.

AVOID:

- Using “controlled outlets” in kitchenettes and break rooms.

III. OPERATIONAL FUNDAMENTALS

When designing for operations and maintenance, it may be useful to consider building spaces and systems in terms of four major fundamental categories: accessibility, durability, reliability, and maintainability/cleanability. Primary O&M considerations according to these fundamentals are discussed below.

1. Accessibility



Consider ease of accessibility, especially for elements that require frequent maintenance.

ARCHITECTURE/INTERIORS

- **Standardize signage design.** Custom design signage requires specialized replacement of room and name signage at occupant change over.

MECHANICAL AND ELECTRICAL SYSTEMS

- **Provide access for immediate operational adjustments.** Means of automating monitoring and enabling remote operation, such as intuitively via the building automation systems (BAS), should be the first consideration. Recognize the added burdens and maintenance costs of locating controls and distribution devices in places with difficult access or where normal schedules of users need to be interrupted.

- **Know schedules.** Know building operation

schedules that indicate when equipment can be taken off-line for service. For spaces that operate 24/7, consider redundant, standby, or temporary connections to avoid loss of service or unexpected costs. Additionally, to reduce maintenance costs, either locate components requiring planned maintenance outside of restricted spaces (such as holding cells) or provide an alternate means of access that does not compromise restricted zones.

- **Minimize periodic maintenance operations.** During design, look for opportunities to reduce the maintenance burden by minimizing periodic maintenance operations. For instance, using direct-drive fans in lieu of belt-driven fans would eliminate periodic belt inspections, period belt replacements, and unplanned service outages caused by belt failure. A second example for new construction or retrofits, would be specifying hardwired sensors for plumbing faucets and flush valves in lieu of battery-operated devices to reduce maintenance and increase the level of service provided to occupants.

- **Incorporate access provisions to minimize maintenance task durations.** These provisions include locating spare parts storage in locations convenient to the points of use, as well as providing stairs, doors, hatches, lifts and hoists of satisfactory capacity and location to allow for maintenance activities.
- **Plan for equipment maintenance accessibility.** Use double-leaf doors as equipment removal access and ensure one leaf is not blocked by equipment. In one project, the penthouse central plant chiller and boiler room are provided with one double-leaf equipment removal door, but half of this door is blocked by one of the chiller's tube pull space. If air-handling units are roof-mounted, make sure they are not too tightly penned in; i.e., have adequate coil pull space.
- **Plan for equipment replacement/removal accessibility.** Small openings, such as single-leaf doors, can generate significant replacement time and costs. Use double-leaf doors to facilitate delivery and removal of equipment such as air-handling units. Also plan travel paths: Crews damaged one project's recovered soft-pine floor when they needed to traverse it hauling a burned-out motor. Additionally, avoid locating equipment in hard-to-reach spaces, such as mounting fan coils and fans above finished ceilings, which require significant time to maintain and make it difficult to respond to emergencies.
- **Plan Access for End-of-Useful-Life Replacement.** Plan for the replacement or upgrading of the prime mover equipment for mechanical, electrical, and plumbing systems to occur several times over the life of the facility. As such, the means of replacement should be inherently obvious and not require imagining dismantling and reconstruction of building components such as walls, floors, and roofs, or protecting less durable or highly valuable features.

LIGHTING/ELECTRICAL

Access to lighting equipment is paramount, since lighting equipment will need repair or replacement at some point in its life.

- **Keep luminaires within reach.** Avoid luminaires located in high ceilings, especially atrium spaces. These prove difficult or impossible to re-lamp. On one project, the lift specified by the design-build team for servicing atrium lights cannot be brought into the space without use of a crane at the building exterior. The weight of the lift risks damaging the floor, necessitating robust floor protection before the lift can be used, thus adding significant O&M labor time and costs.
- **Consider access when selecting lighting equipment.** O&M staff must also be able to access the components *within* the luminaire. Consider both aperture size and disconnect locations of drivers, ballasts, and light sources.
- **Mount luminaires under louvers.** Mounting luminaires above louvers jacks up recurring labor costs, as one or more louvers must be removed to replace a lamp.
- **Consider maintenance accessibility of interior shading.** Make sure that interior shading devices are easy to service or replace. Restricted access requires significant time and expertise in replacing or repairing the shades, adding to the overall operations costs.

2. Durability

SITE/LANDSCAPE

- **Carefully weigh the benefits of exterior water features.** Exterior water features can require significant maintenance and repair costs if they are not adequately designed and installed. Water features are a significant operational cost, especially in locations that regularly experience freezing temperatures, and their use should be weighed carefully.
- **Specify exterior plaza/features for durability.** Exterior plazas can experience deterioration that results in costly maintenance, repair, and replacement. Inappropriate stone selections can lead to substantial repaving costs over the lifecycle of the building. Incorporate aesthetic skateboard protection into the designs.



Specify plazas for durability, with stone selections that have good track records for a given geographic area.

- **Avoid custom garage doors.** Non-standard sizes, custom designs, or other issues affect replacement part availability. When a door goes out of service due to unscheduled maintenance, it can directly impact operations and security of a facility, especially if replacement parts or service technicians are not readily available.

ENVELOPE/STRUCTURE

- **Weigh the value of sunshades.** One project employed vertical aluminum sunshade louvers on its curtain wall. Each vertical louver section is machined into six blades that span from floor to floor and are attached to the mullions of the curtain wall. The orientation of blades varies with the facade orientation and vertical elevation on the building. The louvers create visual interest with minimal solar shading or glare reduction. The louvers are “noisy”; they whistle or rattle as air flows through them, and the sharp, projecting blade edges make window washing difficult, dangerous, and thus, costlier. The sun shades will make eventual glazing replacement far more difficult.
- **Evaluate amount of glazing employed.** While a sawtooth façade can help meet daylighting goals, reorienting the solar exposure by a full 45-degrees can result in higher first costs with the substantial volume of glazing. (Further, unintentional creation of solar energy collecting pockets can increase internal radiant surface temperatures and results in greater discomfort in the perimeter spaces.)
- **Coordinate roof design.** Improper roof design, material selection, and construction can cause significant leaks resulting in long-term maintenance and repair costs, potential health concerns, and mission disruption.
- **Carefully design canopies.** Custom-designed and –installed building entry canopies can become a source of major repair/replacement costs due to their customized design and installation.
- **Avoid proprietary specifications.** Product availability and manufacturer reliability in the local market should be considered as part of the procurement process, greatly reducing increased replacement costs.
- **Assure QA/QC procedures are in place.** One project experienced cracking of one and the delamination of 75 of its ballistic glazing laminated lites. Several units were almost entirely “fogged,”. The cause of these failures should be investigated, but the presence of the visible “contamination” of the interior glass surfaces suggests poor quality control during manufacture.

ARCHITECTURE/INTERIORS

- **Consider durability of interior finishes selections.** Improperly selected and installed interior finishes can cause significant maintenance, repair and replacement time and costs.
- **Carefully monitor concrete mix design, placement, and cure.** Drying shrinkage cracking typically results from high water content in the concrete mix or inadequate curing of the concrete once installed.
- **Don’t install building finishes in an unconditioned space.** In one project, the construction sequencing that allowed this condition may be responsible for persistent splitting that has occurred on the wood surface of wood finishes and furniture in the courtrooms.

- **Avoid light color finishes or floor tiles with numerous grout joints.** Avoid painted floors in areas of high pedestrian traffic or wet locations.
- **Consider revolving doors for atriums, lobbies and vestibules.** Customized lobbies and doors can become a significant source of maintenance, repair and replacement costs. On one project, the main lobby vestibule doors (paired swing doors without a center astragal) require frequent maintenance as the pivot hinges are not well matched to the door leaf sizes and weight. Interior-to-exterior pressure differential delays the door closure, allowing air exchange through the interior vestibule doors when opened.

MECHANICAL

- **Provide more robust systems and equipment to reduce long-term maintenance costs.** These systems, if comparably energy efficient, will yield the lowest total cost of ownership.
- **Consider normal and peak operating points.** Motors should not be driven into their service factor tolerances to meet loads.
- **Design operating sequences with staging.** Design operating sequences with staging among modules of similar equipment to provide both efficient operation and points that do not unnecessarily stress the equipment.

LIGHTING/ELECTRICAL

To increase the likelihood of durable lighting equipment:

- **Use reputable manufacturers that engineer quality products.** Review industry standard test data for projected life of light source, driver, and/or ballast. Provide mock-ups and perform testing on new engineered products, such as LED luminaires, which are constantly evolving.
- **Coordinate the lighting equipment, electrical system, and control system.** Forcing a luminaire to operate outside of its tested parameters will strain the electrical components and light source, resulting in early failure.
- **Review all IP ratings for all luminaires, especially those located in kitchens, showers, restrooms, back-of-house spaces, and exterior environments.** Exterior in-grade luminaires often see moisture penetration and are notorious for early failure.
- **Consider shading.** Excess heat greatly impacts the life of luminaires, especially LED luminaires, and daylight can cause excessive heat gains that will affect a luminaire's lifespan and performance. Consider shading systems can also extend the life of luminaires by reducing direct sunlight exposure.

3. Reliability

SITE/LANDSCAPE

- **Use simple irrigation systems for both interior and exterior landscaping.** Irrigation systems can be complicated and if not designed, installed, and commissioned correctly can cause long term operational, maintenance and repair expenses.
- **Select appropriate plants.** Inappropriate landscaping can cause long term maintenance and replacement expenses, as well as excess water usage.



Use simple irrigation systems and location-appropriate plants to keep landscaping vibrant and healthy.

ENVELOPE/STRUCTURE

- **Avoid custom-designed window shades.** Integrate window treatments into the design process to avoid ill-fitting shades that leave gaps for that allow for sunlight glare. Avoid nonstandard sizes, custom designs, or other issues that restrict or minimize the availability of replacement parts and service personnel to install, replace, and repair them.

MECHANICAL/PLUMBING

- **Keep it simple.** Reduce system designs and their various modes of controls to a simple baseline. This streamlines operations and decreases the optimization period (of energy consumption and occupant comfort), which can be years for today's buildings.
- **Prepare a single-point-of-failure analysis.** Although single points of failure directly compromise a system's reliability, providing redundancy and contingency for many unplanned failure scenarios is cost prohibitive. Design teams should prepare a single-point-of-failure analysis at the end of a project for equipment that requires increased preventative maintenance.
- **Educate the operators.** Simplified systems encourage proper and more complete training of operators, and put an ultimate goal of delivering consistent building performance year-after-year within reach. Operator training should cover all aspects that affect equipment reliability and longevity, as well as setpoints, operating patterns, and schedules for occupant comfort.
- **Control atrium/lobby pressurization.** Inappropriate lobby/atrium design can result in building pressurization problems that can be expensive to monitor, adjust, and maintain. One project experiences unnecessary energy consumption from uncontrolled pressurization. Airflow across its main entrance alcove creates a negative pressure differential that prevents the doors from fully closing and locking, especially during high wind events, creating a significant security concern. Pressurization control works together with humidity control, and both excessive infiltration of outdoor air or exfiltration of treated indoor air wastes energy and water resources. Provide effective pressure monitoring across the desired barriers, specifically at the ground level. Additionally, monitor each level lobby area against readings at both the ground level and the top level.
- **Optimize the BAS.** The BAS can substantially reduce energy efficiency if not optimized to integrate the various building systems for high performance.
- **Optimize the lighting control system for energy savings.** To improve the functionality of the lighting control system: regularly update the lighting control system software; train operations personnel on how to optimize and set the lighting control levels and features; and educate tenants on their personalized lighting control systems.

LIGHTING/ELECTRICAL

Many of the components that are part of a durable lighting system will also increase the likelihood of a reliable system. Without a reliable system, maintenance will be overwhelming, especially with failing drivers.

- **Make lighting controls compatible with luminaires.** If the systems are not compatible, lighting will likely flicker, especially when dimmed. This is especially prevalent with phase dimming technology, such as Magnetic Low Voltage (MLV), Electronic Low Voltage (ELV), forward-phase, and reverse-phase. LED retrofit lamps are the biggest offenders.

- **Commission the lighting control system.** Schedule training with the controls system manufacturer whenever there is a change in operations maintenance staff or control systems' software update. Implement a plan to ensure the lighting control system receives repetitive maintenance from knowledgeable staff, and that the system receives any software updates upon availability. Recommissioning is recommended at least once within 5 years of the initial commissioning.
- **Educate the occupant.** The effective programming of building lighting systems and control in addition to occupant education can dramatically reduce energy costs and improve customer satisfaction. Review the type of sensors used, sensitivity settings, and ranges to avoid occupants from disabling their automatic controls.
- **Standardize lamps/ballasts.** The lack of lamp/ballast standardization in a building can increase O&M times and costs, and delivery delays can be caused by warranties.
- **Optimize lighting.** Balancing and optimizing lighting can improve energy efficiency and occupant satisfaction, especially in open offices. Users near the windows and directly under skylights can have too much light, while furniture and shelving can block adequate light from overhead luminaires from reaching others' desk surfaces.
- **Complete circuit designation and marking.** System and component marking can dramatically reduce O&M time and repair expenses. When a breaker trips, the affected area had to be determined. Also, identifying which breaker feeds an area is very difficult and extremely time consuming.

4. Maintainability/Cleanability

SITE/LANDSCAPE

- **Avoid custom garage doors.** Nonstandard sizes, custom designs, or other issues affect replacement part availability. When a door goes out of service due to unscheduled maintenance, it can directly impact operations and security of a facility, especially if replacement parts or service technicians are not readily available.

ARCHITECTURE/INTERIORS

Storage space: Provide enough storage space to accommodate daily-use items, attic stock items, and large bulk items in convenient and appropriate locations adjacent to use.

Be generous with:

- **Operations and maintenance (O&M) storage.** Limited or poorly located O&M storage can increase O&M staff time and costs getting parts and supplies.
- **Janitorial supply storage.** Undersized and poorly located central supply closets can dramatically increase janitorial time and expenses. Additionally, housekeeping closets on each floor are too small to hold stock materials, requiring increased janitorial time to restock supplies.

- **Equipment storage.** In most projects, there is minimal central storage for custodial equipment, for building service or housekeeping equipment such as scissor lifts or floor washers/waxers. These end up in locations such as the penthouse mechanical rooms or open floor space.

Finishes

Selection of finishes to convey the dignity and stature of federal space is crucial. Selection should also consider finish maintainability to preserve that dignity. Several finishes, such as light-colored flooring, tile, grout, or walls readily show dirt and debris. Other finishes, such as stainless steel, are durable yet difficult to maintain without constant attention.

- **Guard the glass.** Glass finishes for walls and rails present a challenge for cleaning. In one project, custodial personnel reported that the use of glass as a wall and railing finish throughout the courthouse requires considerable increased time to keep these finishes clear and free of fingerprints and other marks. Designs that use interior glass extensively should carefully consider the increased custodial effort associated with these finishes.
- **Watch the wood.** Custom wood flooring can require a unique penetrating oil that requires regular, time-consuming reapplication. This viscous oil can clog the floor finisher/applicator machines. Additionally, when a wood floor abuts woodwork walls, white walls, clear glazing, and stainless steel, all of which make the refinish work challenging. The wood floors are subject to high traffic and resulting marking and abuse. The cleaning and maintenance level is extremely high, requiring specialized staff and equipment, thus increasing costs well beyond the expected average.
- **Spare the steel.** Stainless steel throughout a building, including for the elevator controls, window frames, hand rails, and door hardware, can be subject to fingermarks that require frequent cleaning to maintain the aesthetic. Stainless steel in the restrooms also makes it difficult to maintain a clean look.

LIGHTING/ELECTRICAL



Consider how lights in high ceilings will be cleaned and maintained.

- **Make luminaires accessible for cleaning.** A reliable and durable system will need infrequent maintenance, especially if the luminaires are LED luminaires. However, all luminaires, regardless of light source, will need to be cleaned. This is especially important for exterior luminaires, where dirt build-up over time will drastically reduce light output. Most issues with both maintaining and cleaning luminaires come from inadequate access; plan accordingly.

MECHANICAL

- **Design for service availability.** Consider the availability of qualified service organizations and replacement parts for facilities not located in major metropolitan areas. Base designs around technologies that can be maintained and repaired so that expected reliable service is delivered. Scheduled and predictable service activities can be planned, however breakdowns and failures will cause lapses in mission delivery.
- **Consider security clearances.** Even in the largest service markets, restricted access spaces can vastly reduce the pool of qualified service personnel to a few with suitable clearances and credentials. To reduce maintenance cost, locate components requiring planned maintenance outside of secured boundaries, or provide an alternate means of access that does not compromise restricted zones, would reduce maintenance costs.
- **Use hard-wired hardware.** Battery operated fixtures, included automatic sinks, flush valves, soap dispensers, and paper towel dispensers are difficult to maintain. Not all batteries fail at the same time, and access to under-counter locations is time consuming, so provide a hard-wired connection for any sensor operated restroom fixtures.

5. Additional considerations



Consider wayfinding for public spaces in terms of clear paths, clear signage, and lighting transition from outdoors to indoors.

While O&M concerns can be characterized generally as attributes of accessibility, durability, reliability, and maintainability/cleanability, design of high-performance buildings also requires consideration of O&M in terms of:

- **Wayfinding.** Limited wayfinding and signage can reduce occupant and visitor satisfaction. In general, greater consideration for presenting clear, familiar, and recognizable destinations from the entry lobby that carefully considers arrival and departure paths should be a priority for any public building lobby with a high volume of visitors.
- **Circulation.** Inadequate and ineffective circulation patterns can decrease occupant and visitor satisfaction as well as reduce the efficiency of the facility mission. When employing a large central atrium, carefully consider the location of the vertical circulation and restrooms or consider placing them in more than one location.
- **Safety.** Safety concerns can increase the time and costs to alleviate a hazard, in addition to dramatically increasing liability. For instance, atrium guardrails should not be of a height low enough to tempt people to set down drinks, phones, or even heavy boxes, even if the ledge cants inward to discourage seating.
- **Energy consumption.** For almost 50 years, reducing the amount of energy consumed has been a direct tactic in reducing the costs of long term operations. It is also important for government facilities to demonstrate prudent energy stewardship and promote regional, national, and global community and environmental benefits.

- **Occupant satisfaction.** Increases in occupant satisfaction levels provide beneficial returns of increased worker productivity and customer satisfaction. Higher levels of satisfaction also reduce maintenance costs. ASHRAE Standard 55 provides guidance on managing the numerous contributing factors that impact the bottom line. Designers should demonstrate in the project Basis of Design documents that they understand the needs and characteristics of the space occupants for whom they are selecting systems, and that informed occupants with a means to affect some control of their environments (air speed, air temperature, surface temperature, direct sunlight, glare and contrast) are generally more satisfied.

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V. REFERENCES

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