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Engineering Design Management

Overview

Successful integration of accessible design into the whole design process requires careful consideration of potentially conflicting goals for a project at its earliest stages. The design team must identify conflicts as well as synergies in order to meet project challenges. Sustainability, historic preservation, safety/security, and aesthetics can be problematic for accessibility. The following are a few examples:

- A new city courthouse has lowered office and corridor lighting power density levels.
- Persons with low vision, public and staff, are adversely affected by the requirements because they require brighter lighting to facilitate functioning in the spaces.
- A parking lot for a new office building is designed with pervious pavers to meet sustainability goals. The pavers have openings of 15mm. The pavers located along the accessible route to the building violate the accessibility standard, which requires a maximum opening of 12mm.
- A historic building has a monumental entrance raised 1500mm above grade and accessed only by stairs. The Historic Preservation Officer has determined that altering the entrance to include a wheelchair ramp would destroy historic fabric and irreparably damage the building.
- Accessibility standard provides an exception that allows the use of an alternative entrance in this case in order to provide access, although persons with disabilities will not be able to enter the building through the main entrance.
- A new courthouse has 1200mm x 1200mm security planters installed at the perimeter of the site. The planters are spaced 850mm apart and cross the accessible route into the building. The planters are in violation of accessibility standard, which requires a minimum clearance of 900mm between the planters crossing the accessible route.
- An architect has designed a performing arts center on a steeply sloping site. The entrance location requires persons on foot to negotiate a 3000mm downhill change in level from the street, where there is public transportation available.
- The architect has designed a series of landscaped terraces and stairs to get from street level to the plaza in front of the entrance, but has not included ramps

because they would "compromise" his design. Instead, he uses an enclosed elevator for disabled persons. Two months after the center opens, the elevator has mechanical problems and is out of service.

Identifying potential conflicts at the conceptual level of a project in an integrated design team environment can avoid problems and conflicts such the examples cited and result in a thoughtful and successful project for all of the stakeholders.

Planning for access into the facility

Plan the location of accessible entrances and facility access points when positioning buildings on sites to:

- Limit travel distances for people with disabilities from site arrival points, such as public sidewalks, public transportation stops, and parking, to accessible building and facility entrances.
- Provide accessible routes which require low-effort. Where ever possible, provide walks with no more than 1:20 running slope over ramps. When ramps are required design ramps with lower running slopes and not at the maximum permitted 1:12 permitted.
- Provide equivalent access and travel options to those provided for people without disabilities.
- Provide equivalent, safe, easy, and compliant access into the facility while maximizing security.
- Planning for access to spaces within the facility
- Plan the layout of facility spaces to best accommodate all persons, including people with disabilities, such as:
- Layout spaces whenever possible to limit travel distance between elements within the space.
- Group and centralize spaces to limit the amount of travel required between the spaces.

For instance, in a residential garden style apartment complex, centrally locating the swimming pool and associated amentias is preferred to locating the swimming pool and amenities at one end of the site.

Limit the need for travel between levels and the reliance on elevators and lifts, if possible. Although, obviously not an option between stories of high-rise buildings, limiting the need for vertical access on sites and within one and two story facilities and between intermediate levels of high-rise facilities reduces the likelihood of interruptions in the accessible routes, due to elevator/lift malfunctions, and limits the need to install ramps.

Where vertical access is required between two levels, ramps designed at low grade, are an option to permit guaranteed access. Ramps can often be creatively integrated into designs without negatively impacting the aesthetics.

For instance, integrating ramped access into a swimming pool can avoid the need to install an industrial looking pool lift which can clearly stand out from the overall design.

Choose lighting options which accommodate people with low-vision.

Provide Equal Access and Flexibility

For people with disabilities, access means simply being able to use, enjoy, and participate in the many aspects of society, including work, commerce, and leisure activities. While removing architectural barriers may allow people with disabilities to circulate within and around a facility, other factors, such as transportation, affect their ability to fully participate in activities. Designers and other suppliers of services and goods need to provide equal access for all without undermining the needs of people with disabilities.

What is "Equal Access"?

Providing equal access means ensuring all individuals can make use of transportation, buildings and facilities, programs and services, employment opportunities, and technology. It also means offering all users the same provisions for privacy, security, and safety.

Design professionals can promote equal access by incorporating and integrating accessible and universal design features in a building's design program. Providing equal access begins at the programming and planning phase of a project and requires buy-in from all stakeholders involved in the project.

Critical decisions are made during the initial programming and planning phase of a project which can greatly impact the cost of providing equal access and in some cases affect whether or not equal access can be achieved.

For instance, a building's orientation on a site can affect whether the installation of a ramp is necessary to access the entrance. All design professionals must be aware of the accessibility requirements that apply to the project. Design professionals may benefit from the assistance of consultants specializing in accessibility requirements.

Knowledgeable and detail oriented contractors are key to ensuring that equal access is achieved during the construction phase. If the contractor is not knowledgeable about constructing accessible features equal access may be compromised. In many instances, whether equal access is achieved during the construction process is dependent on a contractor's installation techniques.

The renovated Post Office at Ronald Reagan National Airport provides equal access to the intake windows, Arlington, VA. Note the accessible window on the far right.

Why Provide "Equal Access"?

Providing equal access removes discrimination and protects human rights. An accessible built environment provides the opportunity for all people to fully participate in and contribute to their families, communities, and society. Equal access offers individuals the occasion to improve the quality of life and standard of living for themselves, their families, and other people in the world. Finally, providing equal access is required, to varying degrees, in order to meet applicable building codes, accessibility standards, and accessibility guidelines.

How Do We Achieve "Equal Access"?

Equal access must be an integral part of the life-cycle process:

- planning,
- programming,
- design,
- construction, and
- operation, and maintenance of buildings and facilities, not an afterthought.

Accessible features should blend seamlessly with the design. All stakeholders on the project should work together from the start to coordinate and optimize the design of the site and the building. A building and its site should be designed as an integrated whole, rather than as a collection of isolated systems.

Design and construction decisions impact accessibility. Single building elements or systems should not be added, deleted, or modified anytime in the life of the building until they are coordinated and evaluated with the other elements and systems in the whole building package and with all parties involved.

Keep in mind that "equal access" applies to programs, services, benefits, transportation, fixtures, furnishings, equipment, employment opportunities, and technology.

Beyond Accessibility to Universal Design

Accessibility laws establish minimum requirements that protect people with disabilities from discrimination in the built environment.

Universal design, the term for this revised approach, was based on the premise that the environment could be much more accessible than the minimum requirements of law required if designers focused attention on improving function for a large range of people.

At the broadest level, universal design is concerned with designing for diversity and equity.

Definitions of Universal Design

Universal design (UD) is also called inclusive design, design for all, or life span design. As initially conceived, UD was focused on usability issues. "The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design" (Mace, 1985). In the last ten years, the emphasis was broadened to wider issues of social inclusion.

A newer definition is more relevant to all citizens without ignoring people with disabilities. It states that universal design is, "a process that enables and empowers a diverse population by improving human performance, health and wellness, and social participation" (Steinfeld and Maisel, 2012). In short, universal design makes life easier, healthier, and friendlier for all.

Universal design increases the potential for developing a better quality of life for a wide range of individuals. It also reduces stigma by putting people with disabilities on an equal playing field. While it does not substitute for assistive technology, universal design benefits people with functional limitations and society as a whole. It supports people in being more self-reliant and socially engaged. For businesses and government, it reduces the economic burden of special programs and services designed to assist individual citizens, clients, or customers.

Proponents of universal design must recognize that products and environments can never be fully usable by every person in the world, but that services, management practices, and policies can benefit from universal design thinking. Universal design should therefore be considered a process rather than an end state. There is never any end to the quest for improved usability, health, or social participation, so attention to more than just the built environment is needed to achieve these three broad outcomes.

The following table provides some examples of the differences between universal design and accessible design.

Universal	Accessible
A universally designed home plan costs the same as any other plan to build that anyone can purchase	A custom designed home based on an existing plan but requires additional costs for the redesign and custom construction details
Home improvement services that incorporate universal design as a basic service	Home modifications services by a contractor who charges more for her specialized knowledge of design for disability and aging
Automobile instruments and controls customizable to accommodate differences in perceptual abilities, stature, motor abilities, and preferences	Assistive technology used to adapt an automobile display for people with special needs
A no step building entry that everyone can use easily and together	A building entry with a ramp at the side that is out of the way for all visitors but is accessible by code
A hotel that has 100% universally designed rooms in a variety of types	A hotel that has only the code-required percentage of accessible rooms

APPLICATION: Principles of Universal Design

The "Principles of Universal Design" were developed by a team of U.S. experts organized by the Center on Universal Design at NC State University in the 1990's. Accompanied by a set of guidelines for each Principle, they were a valuable tool for clarifying universal design for early adopters, and are still widely used today.

The Principles of Universal Design:

1. Equitable Use
2. Flexibility in Use
3. Simple and Intuitive
4. Perceptible Information
5. Tolerance for Error
6. Low Physical Effort
7. Size and Space for Approach and Use

Goals of Universal Design

The eight Goals of Universal Design were recently developed in an effort to update the Principles, clarify the concept of Universal Design, incorporate human performance, health and wellness, and social participation as outcomes, and address contextual and cultural issues.

For example, there are many sources of contextual differences, such as topography, economic development levels, cultural norms, and local values, which influence the way designers apply UD Principles and/or Goals. Increasingly, high value is placed on preserving cultural resources like historic buildings and natural resources. Attempts to enhance accessibility, however, often conflict with these two goals. Universal design must address this conflict to overcome perceptions that it gets in the way of reaching other important design goals.

One barrier to adoption of universal design in middle- and low-income countries is the perception that it is often perceived as idealistic, expensive, or an imposition of Western values. It is realistic and appropriate to acknowledge that design strategies will differ or be adapted in different places and by different cultures. In some places, achieving the level of accessibility required by Western norms could be counterproductive.

Thus, it is important that universal design strategies also address cultural values associated with social, economic, and physical context. In addition to addressing these concerns, the eight Goals of Universal Design were also conceived to link universal design to bodies of knowledge and identify measurable outcomes.

1. **Body fit.** Accommodating a wide a range of body sizes and abilities
2. **Comfort.** Keeping demands within desirable limits of body function
3. **Awareness.** Insuring that critical information for use is easily perceived

4. **Understanding.** Making methods of operation and use intuitive, clear, and unambiguous
5. **Wellness.** Contributing to health promotion, avoidance of disease, and prevention of injury
6. **Social integration.** Treating all groups with dignity and respect
7. **Personalization.** Incorporating opportunities for choice and the expression of individual preferences
8. **Cultural appropriateness.** Respecting and reinforcing cultural values and the social, economic and environmental context of any design project.

Expanding Adoption

Universal design has not been adopted as extensively within the design community as some other recent design movements (e.g., sustainability, historic preservation). One challenge facing adoption is a continued perception of universal design as design for disability. To reach professionals, continuing education and the development of communities of practice, especially among educators, is a priority.

The most direct way to make key stakeholders (e.g., builders, designers, end users) more aware of universal design is through widely used media like television and the Internet. At this stage in the evolution of UD, it is important not to limit models of practice to "the one best way" so that each sector of industry and professional practice can have a selection of practices to fit with their needs.

There are good examples of the value of universal design for all stakeholders. Examples of UD features in buildings include automated doors, which provide an entrance for people of all abilities; integrated furniture components and power and communication systems that make outlets more convenient; and multi-sensory interactive way finding models that enable almost any person to comfortably operate and learn from a public map and directory system.

EMERGING ISSUES

As a result of UD's growing popularity, many new issues have captured the attention of design professionals and their colleagues in related professions. Those issues with a close relationship to universal design include aging in place, sustainability, workplace design, public spaces, and social justice. Universal design has much to contribute to solving any social problem in which usability and social participation play a major role in design response.

Aging in Place: A large majority of individuals want to age where they currently live. Adults over the age of 65 found that almost 90 percent want to remain in their own home for as long as they are able and 80 percent anticipated permanently living in their current residence. Aging in place offers numerous social and financial benefits, and promotes keys to successful aging such as life satisfaction, health, and self-esteem.

Another report describes factors that often prevent older adults from aging in place including auto-oriented land uses in their communities and a lack of access to transportation. Others who remain in their homes but are unable to make necessary renovations risk living with barriers that endanger their safety and limit their ability to participate in the community.

To remain in their own homes while aging, people need housing designs that can be adapted to wider range of health conditions than traditional designs allow. Encouraging housing producers to adopt universal design features is a key aspect of design for aging in place. This includes a no-step entry, bathrooms on an accessible floor level, potential for a sleeping space on an accessible level, good lighting, efficient space planning, and other features that reduce effort and accommodate short-term and chronic disabilities.

Common Aging-in-Place Features:

- One no-step path to a no-step entry that can be at the front, side, rear, or through a garage (6-12mm thresholds)
- No step access to patios, balconies, and terraces (6-12mm thresholds)
- Doorways have at least a 850mm wide clear opening with appropriate approach clearances
- Door handles are 850-950mm from the floor
- Hallways and passageways are 1050mm clear minimum
- Access to at least one full bath on the main floor with reinforced walls at toilets and tubs for the future installation of grab bars
- Cabinetry in kitchen that allows a person to work in a seated position
- Light switches and electrical outlets 600-700mm from finished floor
- Stairways have tread widths at least 275mm deep and risers no greater than 175mm high
- Good lighting throughout the house including task lighting in critical locations (e.g. under kitchen cabinets)
- Non-glare surfaces
- Contrasting colors to promote good perception of edges and boundaries

- Clear floor space of at least 750-1200mm in front of all appliances, fixtures, and cabinetry
- Front-loading laundry equipment
- Ample kitchen and closet storage or adjustable shelving within 700-1200mm.
- Comfortable reach zones

This image from the LIFEhouse™ shows many levels of lighting, multiple work center levels, and fixtures and appliances with universal design features. The home was the recipient of the National Association of Home Builders 2012 Gold Award for Best Universally Designed Home.

Workplace

Universal design is a critical consideration when designing work place environments for several reasons:

- o 21.3 million (nearly 65%) of American adults with disabilities that are of working-age (16–64 years old) live with a chronic conditions that inhibit their capacity to maintain employment (Waldrop & Stern, 2003);
- o typically adults spend a significant time working, thus making work environments important spaces in daily life (Sanford, 2012).

Good design of the workplace can help increase participation of people with disabilities in the workforce, and can help to ensure that fewer accommodations will be needed if an employee has a disability. Additionally, achieving the highest level of usability in the workplace environment increases overall task efficiency, productivity, employee morale, and general safety and also helps employers attract and keep a broad and diverse work force.

Common Workplace Features:

- All controls within the comfortable reach zone of between 24 inches (610 mm) and 48 inches (1220 mm) above the floor
- Ample and secure storage for employee's personal possessions within the comfort range of (610 mm) and 48 inches (1220 mm) above the floor
- At least one automated door to the building, preferably one closest to employee parking or public transportation
- Counter heights for workstations should be adjustable to fit a work force with a wide range of statures and visual abilities
- Cubicles and other devices to give individual workers some control over noise
- Designated break areas that are quiet and comfortable, to allow workers a place to recover from work demands and socialize with others
- Height adjustable work surface between 28 inches (715 mm) and 32 inches (815 mm), with frequently used items stored within 24 inches (610) and 48 inches (1220 mm) and within a 24 inch (710 mm) maximum of reach arch from the elbow
- Sound absorbent materials on walls and floors to keep ambient noise levels as low as possible where background noise cannot be eliminated
- Storage containers that provide the option of carrying, pushing, pulling, or rolling
- Systems for employees to adjust light levels at their workspaces to best fit the requirements for their specific tasks, individual abilities, and preferences
- Wheeled chair with adjustable height seat, reclining tilt function, lumbar support, adjustable arm rests, and a high back to support neck and head
- Workstations situated so employees can communicate effectively with visual and/or verbal modes of communication
- Workstations that accommodate both standing and seated positions, also referred to as "sit-stand" workstations used wherever possible

Public Spaces

Public spaces include facilities open to the public such as stores, restaurants, amusement parks, parks and other recreation facilities, street rights-of-way, and transportation systems. Public accommodations are a critical domain for universal design because they are the site of key participation activities, including engagement in civic affairs, employment, recreation, education, and community mobility.

(Left) Provide workplace options (e.g., standing workstations) that enable employees to periodically get relief from the stress of standing or sitting for long periods of time, and work in an environment that is most productive for them. *(Right)* Provide employees with access to environmental controls and light switches to allow them to adjust the temperature and light levels to best fit the requirements for their specific tasks, individual abilities, and preferences.

Common Universal Design Features in Public Spaces

- A tactile guide path in a museum helps all visitors find the information desk.
- Drinking fountains grouped with other amenities to make them easier to locate
- Directional signage/way finding cues throughout
- Lighting provided along outdoor pathways
- Nodes connected directly by pathways
- Resting places throughout the site
- Restrooms appropriately sized to support large numbers of users at the same time
- Signage placed within sight lines
- Signage in alternate languages, as well as in English
- Visual and tactile warning surfaces
- Walls, fences, and landscape features used for guidance to key destinations

(Left) A store entrance with automated doors allows all customers to enter the same way. *(Right)* Clear walkways, expanded corners, safety islands, and bike lanes enhance pedestrian, bicyclist, and driver safety.

Hippo Water Roller. This design, inspired by a lawn roller, reduces the need for lifting and carrying and allows an individual to carry more water at one time (hipporoller.org).

Social Justice

Throughout the world, designers with a sense of social responsibility are concerned that good design, like many other resources of society, is a commodity that many cannot afford. Although initially focused on disability rights, universal design can focus on any civil rights issue because ultimately design for diversity is concerned with social justice for all. Thus, universal design should give attention to supporting access to housing, education, healthcare, transportation, and other resources in society for all those groups that have been excluded from full participation. Universal design is particularly appropriate in the context of design for low-income minority groups, which often have higher rates of disability than the general population.

Sustainability

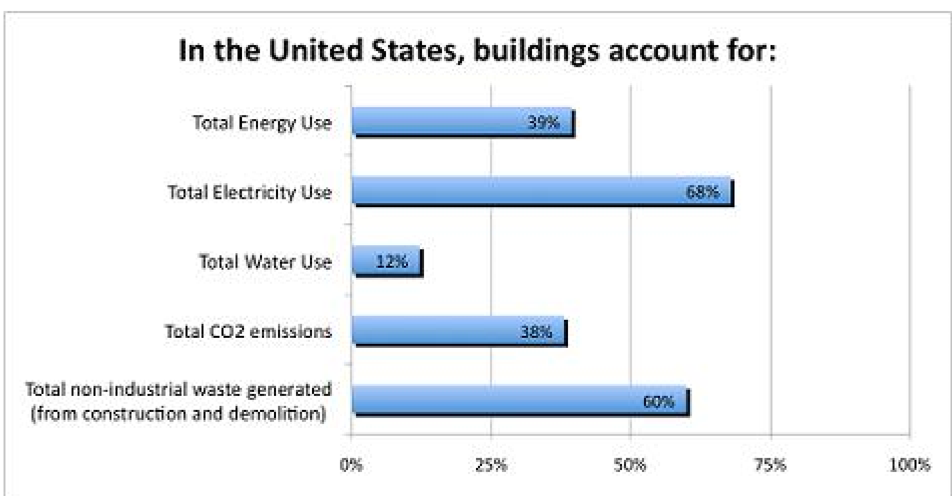
Building construction and operations can have extensive direct and indirect impacts on the environment, society, and economy, which are commonly referred to as the 3 P's ('People', 'Planet', 'Pocketbook'). The field of sustainable design seeks to balance the needs of these areas by using an integrated approach to create win-win-win design solutions.

The main objectives of sustainable design are to reduce, or completely avoid, depletion of critical resources like energy, water, and raw materials; prevent environmental degradation caused by facilities and infrastructure throughout their life cycle; and create built environments that are livable, comfortable, safe, and productive.

Buildings use resources (energy, water, raw materials, and etc.), generate waste (occupant, construction and demolition), and emit potentially harmful atmospheric emissions. Building owners, designers, and builders face a unique challenge to meet demands for new and renovated facilities that are accessible, secure, healthy, and productive while minimizing their impact on society, the environment, and the economy. Ideally, building designs should result in net positive benefits to all three areas.

In addition to including sustainable design concepts in new construction, sustainable design advocates commonly encourage retrofitting existing buildings rather than building anew. Retrofitting an existing building can often be more cost-effective than building a new facility.

Designing major renovations and retrofits for existing buildings to include sustainable design attributes reduces operation costs and environmental impacts, and can increase building resiliency. The embodied energy of the existing building, a term expressing the cost of resources in both human labor and materials consumed during the building's construction and use, are squandered when the building is allowed to decay or be demolished.



While the definition of *sustainable building design* is constantly changing, six fundamental principles persist.

1. Optimize Site Potential

Creating sustainable buildings starts with proper site selection, including consideration of the reuse or rehabilitation of existing buildings. The location, orientation, and landscaping of a building affect local ecosystems, transportation methods, and energy use. It is important to incorporate smart growth principles into the project development process, whether the project is a single building, campus, or military base.

Siting for physical security is a critical issue in optimizing site design, including locations of access roads, parking, vehicle barriers, and perimeter lighting. Whether designing a new building or retrofitting an existing building, site design must integrate with sustainable design to achieve a successful project. The site of a sustainable building should reduce, control, and/or treat storm water runoff. If possible, strive to support native flora and fauna of the region in the landscape design.

2. Optimize Energy Use

With continually increasing demand on the world's fossil fuel resources, concerns for energy independence and security are increasing, and the impacts of global climate change are becoming more evident, it is essential to find ways to reduce energy load, increase efficiency, and maximize the use of renewable energy sources in federal facilities. Improving the energy performance of existing buildings is important to increasing our energy independence. Government and private sector organizations are increasingly committing to building and operating net zero energy buildings as a way to significantly reduce our dependence on fossil fuel-derived energy.

3. Protect and Conserve Water

In many parts of the country, fresh water is an increasingly scarce resource. A sustainable building should use water efficiently, and reuse or recycle water for on-site use, when feasible. The effort to bring drinkable water to our household faucets consumes enormous energy resources in pumping, transport, and treatment. Often potentially toxic chemicals are used to make water potable. The environmental and financial costs of sewage treatment are significant.

4. Optimize Building Space and Material Use

The world population continues to grow (to over 9 billion by 2050), natural resource use continues to increase, and the demand for additional goods and services stresses available resources. It is critical to achieve an integrated and intelligent use of materials that maximizes their value, prevents upstream pollution, and conserves resources. A sustainable building is designed and operated to use and reuse materials in the most productive and sustainable way across its entire life cycle.

The materials used in a sustainable building minimize life-cycle environmental impacts such as global warming, resource depletion, and human toxicity. Environmentally preferable materials have a reduced effect on human health and the environment and contribute to improved worker safety and health, reduced liabilities, reduced disposal costs, and achievement of environmental goals.

5. Enhance Indoor Environmental Quality (IEQ)

The indoor environmental quality (IEQ) of a building has a significant impact on occupant health, comfort, and productivity. Among other attributes, a sustainable building maximizes daylighting, has appropriate ventilation and moisture control, optimizes acoustic performance, and avoids the use of materials with high-VOC emissions. Principles of IEQ also emphasize occupant control over systems such as lighting and temperature.

6. Optimize Operational and Maintenance Practices

Considering a building's operating and maintenance issues during the preliminary design phase of a facility will contribute to improved working environments, higher productivity, reduced energy and resource costs, and prevented system failures. Encourage building operators and maintenance personnel to participate in the design and development phases to ensure optimal operations and maintenance of the building.

Designers can specify materials and systems that simplify and reduce maintenance requirements; require less water, energy, and toxic chemicals and cleaners to maintain; and are cost-effective and reduce life-cycle costs. Additionally, design facilities to include meters in order to track the progress of sustainability initiatives, including reductions in energy and water use and waste generation, in the facility and on site.

Facilities operations and maintenance encompasses all that broad spectrum of services required to assure the built environment will perform the functions for which a facility was designed and constructed. Operations and maintenance typically includes the day-to-day activities necessary for the building and its systems and equipment to perform their intended function.

Operations and maintenance are combined into the common term O&M because a facility cannot operate at peak efficiency without being maintained; therefore the two are discussed as one.

Real Property Inventory (RPI) — Provides an overview on the type of system needed to maintain an inventory of an organization's assets and manage those assets.

Computerized Maintenance Management Systems (CMMS)—Contains descriptions of procedures and practices used to track the maintenance of an organization's assets and associated costs.

Computer Aided Facilities Management—is an approach in Facilities Management that includes creation and utilization of Information Technology (IT)-based systems in FM practice.

O&M Manuals—it is now widely recognized that O&M represents the greatest expense in owning and operating a facility over its life cycle. The accuracy, relevancy, and timeliness of well-developed, user-friendly O&M manuals cannot be overstated. Hence, it is becoming more common for detailed, facility-specific O&M manuals to be required as a part of the total commissioning process.

Janitorial/Cleaning — As the building is opened the keys are turned over to the janitorial, custodial or housekeeping staff for interior "cleaning" and maintenance. Using environmentally friendly cleaning products and incorporating safer methods to clean buildings provides for better property asset management and a healthier workplace. Grounds maintenance and proper cleaning of exterior surfaces are also important to an effective overall facility maintenance and cleaning program.

Historic Buildings Operations and Maintenance—this is a unique and complex issue: balancing keeping old equipment running while contemplating the impact of installing new more efficient equipment. Further, cleaning of delicate surfaces and artwork require the use of products that are less likely to damage these surfaces, while providing a healthy environment for the building's occupants. Maintaining strict temperature and humidity control to protect artwork and antiquities is an additional challenge for the O&M staff.

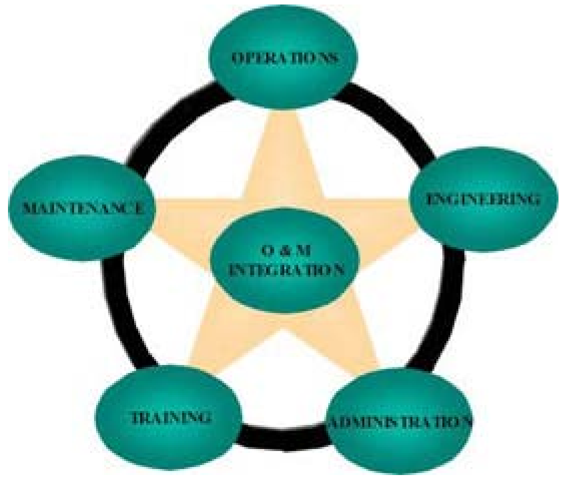
The scope of O&M includes the activities required to keep the entire built environment as contained in the organization's Real Property Inventory of facilities and their supporting infrastructure, including utility systems, parking lots, roads, drainage structures and grounds in a condition to be used to meet their intended function during their life cycle.

These activities include preventive and predictive (planned) maintenance and corrective (repair) maintenance. Preventive Maintenance (PM) consists of a series of time-based maintenance requirements that provide a basis for planning, scheduling, and executing scheduled (planned versus corrective) maintenance. PM includes adjusting, lubricating, cleaning, and replacing components.

Time intensive PM, such as bearing/seal replacement, would typically be scheduled for regular (plant or "line") shutdown periods. Corrective maintenance is a repair necessary to return the equipment to properly functioning condition or service and may be either planned or un-planned. Some equipment, at the end of its service life, may warrant overhaul. Per DOD, the definition of overhaul is the restoration of an item to a completely serviceable condition as prescribed by maintenance serviceability standards.

Requirements will vary from a single facility, to a campus, to groups of campuses. As the number variety and complexity of facilities increase, the organization performing the O&M should adapt in size and complexity to ensure that mission performance is sustained. In all cases O&M requires a knowledgeable, skilled, and well trained management and technical staff and a well planned maintenance program. The philosophy behind the development of a maintenance program is often predicated on the O&M organization's capabilities. The goals of a comprehensive maintenance program include the following:

1. Reduce capital repairs
2. Reduce unscheduled shutdowns and repairs
3. Extend equipment life, thereby extending facility life.
4. Realize life-cycle cost savings , and
5. Provide safe, functional systems and facilities that meet the design intent.



A critical component of an overall facilities O&M program is its proper management. Per FEMP, the management function should bind the distinct parts of the program into a cohesive entity. The overall program should contain five distinct functions: Operations, Maintenance, Engineering, Technology, and Administration (OMETA). Beyond establishing and facilitating the OMETA links, O&M managers have the responsibility of interfacing with other department managers and making their case for ever shrinking budgets.

Accessible Design and the Relationship to Sustainable Design

Whole building design must consider the relationship between accessible and sustainable design. Simply put, buildings which are not designed to be accessible are not sustainable. A sustainable building is sensitive to the environment and to its users. Designing buildings for equitable use by the greatest number of people can be achieved by complying with regulatory accessibility requirements, incorporating Universal Design and Visitability concepts, and including adaptable design features.

For some time now, laws and codes have required accessible design in most building types. When required accessibility is not incorporated at the onset of design or during construction, the risk of complaints of non-compliance and even litigation exists. The result could include required retrofits. Retrofitting buildings due to lack of accessibility compliance, which can create unnecessary waste and energy, is not consistent with the goals of sustainability.

Automatic lighting and fixture controls are a win-win for both sustainability and accessibility.

Sustainability and accessibility are intrinsically linked in the design process. For example, when locating buildings on a site to optimize solar orientation, accessibility of the building entrance(s) must be taken into consideration. Will optimal solar orientation create a condition that results in building entrances which are located on a circuitous route from site arrival points? Accessibility must also be considered when selecting sustainable building materials.

For example, pervious pavers may be specified to increase water infiltration, but if the installation of the pavers results in wide spaces between them or an unstable ground surface, then accessibility is not achieved.

Whole building design requires a balanced and integrated approach to all the design objectives, including accessibility.

Classroom Acoustics

Acoustical performance is an important consideration in the design of classrooms. Research indicates that levels of background noise and reverberation, little noticed by adults, adversely affect learning environments for young children, who require optimal conditions for hearing and comprehension.

Poor classroom acoustics are an additional educational barrier for children who have hearing loss and those who use cochlear implants, since assistive technologies amplify both wanted and unwanted sound. Children who have temporary hearing loss, who may comprise up to 15% of the school age population according to the Centers for Disease Control, are also significantly affected, as are children who have speech impairments or learning disabilities. Kids whose home language is different than the teaching language are also at additional risk of educational delay and failure.

Lighting Levels and Low Vision

The Low Vision Design Committee (LVDC) of NIBS recognizes that the needs of all occupants of the built environment, including those with low vision, should have adequate lighting levels. Through improvements in designs and operational procedures for new and existing facilities the committee is working to develop standards that will enhance the function, safety, and quality of life. The LVDP was formed to organize activities that would support four major needs identified.

- Designers need a better understanding low vision persons' needs
- Clinicians need a better understanding lighting and accessibility
- Everyone needs a common vocabulary
- Standards need to balance reduced energy consumption and adequate illumination for all building users.

21st Century Work Space

The high cost of office space in many urban areas, shrinking budgets for space, the use of telework, flexible work scheduling, hoteling and virtual work, and new technologies such as teleconferencing, web casting, telepresence, virtual phones, and WebEx have moved designers to plan downsized office space where the number of work stations is significantly lower than the number of employees in order to maximize the use of space, whether owned or leased. In this arrangement, managers and employees share the same work space and there are no private offices.

A docking station for a laptop computer and single or double monitors are provided at each work station. There are no desktop computers, so each person must bring their laptop computer with them on an office day. There are also no reception counters or spaces. Common "break rooms" contain cabinets, counters, refrigerators and microwave ovens that may be shared by multiple organizations. Common shared printers are kept to a minimum, and there are no individual printers. There are also communal coat closets adjacent to the work space for coats, umbrellas, etc.

Employees with disabilities who require special assistive technology, as well as certain employees who use a large amount of technology required for their jobs that is not portable require special consideration and exceptions to the general way the space is utilized, and are provided with dedicated work stations. However, because persons with certain disabilities require provisions such as higher light levels and significant glare reduction, audio amplification, etc., the commonly shared office space could prove to be an obstacle for them even though they have dedicated work stations.

Aesthetics

In *The Ten Books of Architecture* the ancient Roman architect Vitruvius stated that a building should meet obligations of commodity, firmness, and delight. Commodity addresses how a building serves its function and can be made more useful. Firmness means a building's ability to stand up to natural forces over time. Delight refers to aesthetics.

Aesthetics is a branch of philosophy devoted to beauty. It dissects visual elements like proportion and line, as well as other formal qualities—auditory, tactile, olfactory, thermal, and even kinesthetic—that achieve beauty. It also studies changing concepts, such as political environment or social status, that affect people's perception of what is beautiful. In the case of architecture, these underlying concepts may include branding, image ability, ideas about community, and the importance of technology. Not surprisingly, then, standards of beauty vary according to time and culture.

So do the ways that beauty is manifest-which is known as style. The early 21st century is a remarkable period in architecture because it features pre-modern historical styles in great variety as well as Modernist forms. Meanwhile, forms of contemporary architecture are continually evolving; they cannot be pinned down as a style until a critical mass of buildings has consistently satisfied one set of compositional and conceptual criteria.

Left Air Force Academy Cadet Chapel (more) *Right* Jose V. Toledo U.S. Post Office and Courthouse, Old San Juan, Puerto Rico. Credits: Finegold Alexander + Associates, and GSA.

Left: National Oceanic and Atmospheric Administration, Satellite Operations Facility, Suitland, MD. Credits: Morphosis and GSA. *Right:* Howard M. Metzenbaum U.S. Courthouse, Cleveland, OH. Credit: GSA

Today's variety of expression can be seen in these two examples of federal building projects

Contemporary culture advocates diversity of styles, even in cases of historic preservation. It also encourages the development of new architectural languages. In response to this openness, designers agree that aesthetically successful architecture comes from an integrated approach. By correctly formulating a project's purpose, seeking inspiration in programmatic requirements, and engaging in team-wide design reviews, an architect most effectively arrives at a solution that is as delightful as it is cost-effective, secure/safe, sustainable, accessible, and functional/operational.

Returning to Vitruvius, one can conclude that his three standards of architecture reinforce one another. Good architecture achieves useful, humane, and economical results, and a building expresses those qualities regardless of style.

A fully integrated building promises to be durable in way that Vitruvius may not have envisioned: It will inspire a community to find ways to use it even when the original program is no longer relevant.

With an eye to integration, an architect makes aesthetic decisions in full collaboration with the client, building users, other consultants, and the public. Therefore it is important for the client and building users to be well informed about the possibilities of architecture. They can assist the design team in conceiving a building that meets the most needs.

Understanding the Language and Elements of Design

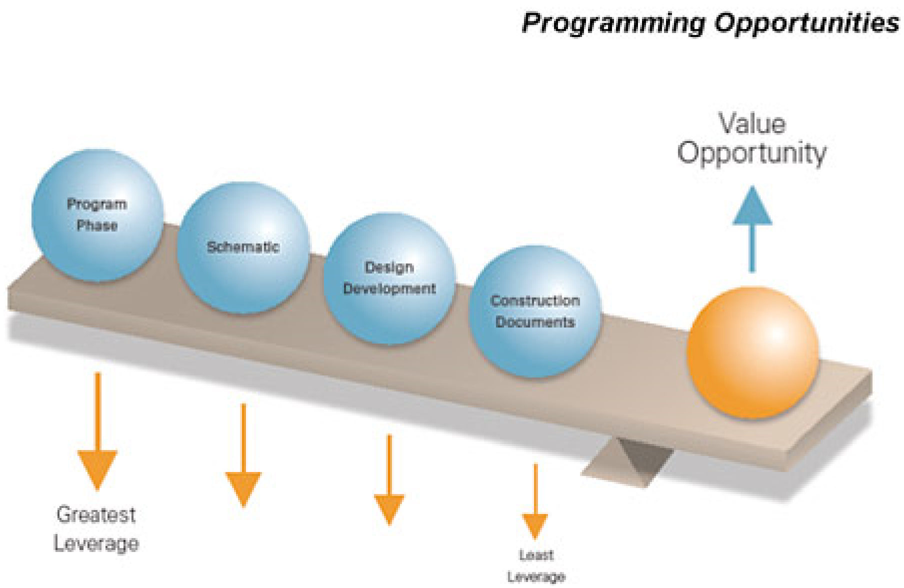
Architects use specific terminology to describe fundamental elements of a building, and to assess its design quality. A client's fluency with this vocabulary improves the architect's application of the elements it represents.

Engage the Integrated Design Process

An integrated design process interlaces the multiple disciplines that inform a building. A series of steps can provide an orderly flow to this dialogue, and the full and constructive participation of all members of the design and delivery team will ensure the best results.

The design awards programs of professional societies, the federal government, and industry trade associations offer additional insight into aesthetic values at a given time in history.

Design Stage Management



Once a design team has been agreed upon and assembled, the owner needs to coordinate and manage the project's design phases. Design management requires the oversight of schedules and budgets; review of key submissions and deliverables for compliance with program goals and design objectives; verification of stakeholder input for inclusion; verification of construction phase functional testing requirements; and appropriate application of the owner's design standards and criteria.

This stage should also define the criteria for assessing quality measurement to ensure the project's success. Determining appropriate goals and objectives at the beginning of the process, during a visioning session, and measuring their implementation over the life cycle of building and construction has been proven to increase overall building quality and reduce project costs and timing to delivery.

Delivering and Measuring Building Quality

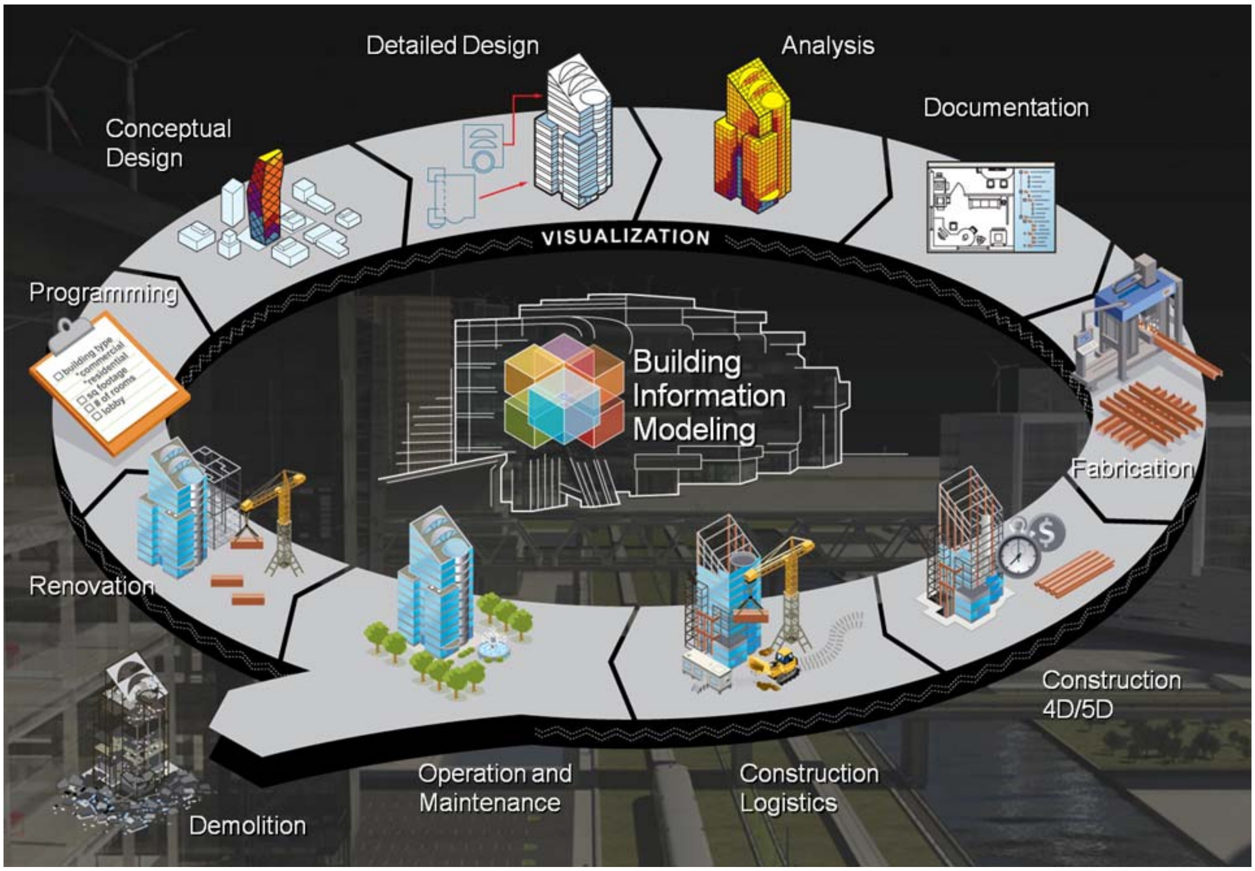
Good design is derived from a complex and creative process encompassing a wide range of activities, elements and attributes. A standard for measuring building quality has been created by the Construction Industry Council (CIC) and it measures the key attributes that constitute good design and produces high performance buildings.

The CIC has developed the Design Quality Indicator (DQI) a standard method of assessing the quality of buildings in three main areas: Functionality, Build Quality and Impact. Functionality is concerned with the arrangement, quality and inter-relationships of space and the way in which the building is used.

Build Quality relates to the engineering performance of a building which includes structural stability and the integration and robustness of systems, finishes and fittings. Impact refers to the building's ability to create a sense of place and have a positive effect on the local community and environment. DQI also encompasses the wider effect the design may have on the art of building and architecture. It is the interplay between all of these factors that creates a truly high performance building. The overlapping nature is demonstrated below:

Building Information Modeling

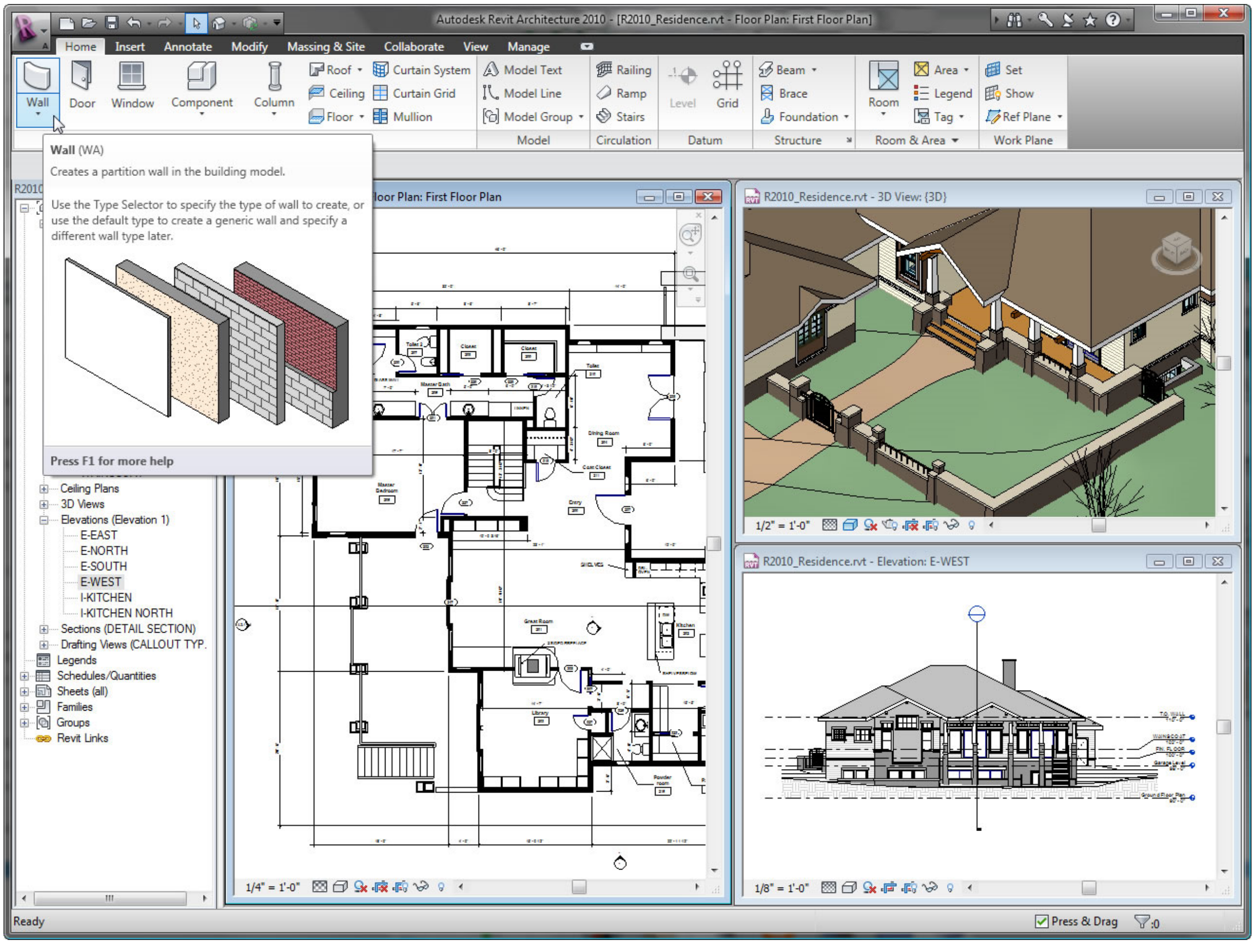
A Building Information Model (BIM) is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. BIM has the potential to truly integrate accessibility into a project by considering accessibility early and throughout all phases of the project.



Using Building Information Modeling (BIM)

Building Information Modeling (BIM) is the process of generating and managing building data during its life cycle. Typically it uses three-dimensional, real-time, dynamic building modeling software to increase productivity in building design and construction. The process produces the Building Information Model (also abbreviated BIM), which encompasses building geometry, spatial relationships, geographic information, and the quantities and properties of building components.

Utilizing BIM has the potential to save project time and cost and increase overall productivity of construction and delivery of building projects with less rework, design, and construction errors.



The advantages of BIM over the traditional design and construction process are significant (source: Construction Delivery Systems, Lorence H. Slutzky, 2008):

1. BIM single data entry into one model avoids the opportunity for inconsistency and error of repeated input of identical data in multiple media. Data once entered or altered is available in the single current model available to all.
2. BIM design efficiency reduces the cost of design and preparing contract documents.
3. BIM base information is uniform and shared with all participants.
4. BIM three dimensionality and software identify physical conflicts between elements reducing significant construction delay, and extraordinary additional expense. Where modifications are suggested, the impact of the proposed changes are immediately apparent, subject to evaluation and reconsideration.
5. BIM three dimensionality assists in sequencing and constructability reviews.

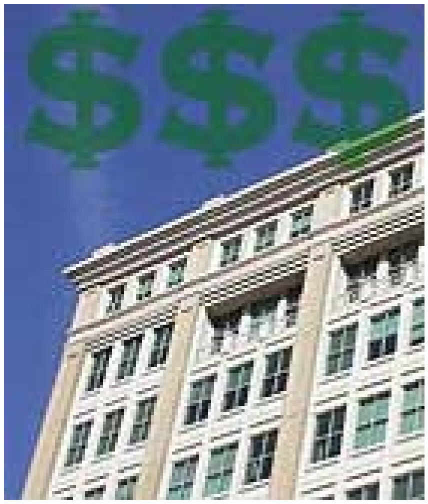
6. Confidence in shop drawing and fabrication accuracy is improved by BIM because the model can provide construction details and fabrication information. More materials can be fabricated more economically off site under optimal conditions due to the confidence in the accuracy of the fabrication.
7. BIM can link information to quantify materials, size and area estimates, productivity, material costs and related cost information.

Overall, the BIM digital model becomes a rehearsal of construction and can help identify conflicts and their resolution before actual construction dollars are spent.

Cost–Effective

"We no longer build buildings like we used to, nor do we pay for them in the same way. Buildings today are...life support systems, communication terminals, data manufacturing centers, and much more. They are incredibly expensive tools that must be constantly adjusted to function efficiently. The economics of building has become as complex as its design." (Wilson, in foreword to Ruegg & Marshall, 1990)

Every owner wants a cost-effective building. But what does this mean? In many respects the interpretation is influenced by an individual's interests and objectives, and how they define "cost-effective".



- Is it the lowest first-cost structure that meets the program?
- Is it the design with the lowest operating and maintenance costs?
- Is it the building with the longest life span?
- Is it the facility in which users are most productive?
- Is it the building that offers the greatest return on investment?

While an economically efficient project is likely to have one or more of these attributes, it is impossible to summarize cost-effectiveness by a single parameter. Determining true cost-effectiveness requires a life-cycle perspective where all costs and benefits of a given project are evaluated and compared over its economic life.

In economic terms, a building design is deemed to be cost-effective if it results in benefits equal to those of alternative designs and has a lower whole life cost, or total cost of ownership.

For example, the HVAC system alternative that satisfies the heating and cooling requirements of a building at the minimum whole life cost, is the cost-effective HVAC system of choice. Components of the whole life cost include the initial design and construction cost, on-going operations and maintenance, parts replacement, disposal cost or salvage value, and of course the useful life of the system or building.

The challenge is often how to determine the true costs and the true benefits of alternative decisions. For example, what is the economic value in electric lighting savings *and* productivity increases of providing daylight to workplace environments? Or, what is the value of saving historic structures? Alternately, what is the cost of a building integrated photovoltaic system (BIPV), given that it may replace a conventional roof?

The following three overarching principles associated with ensuring cost-effective construction reflect the need to accurately define costs, benefits, and basic economic assumptions.

1. Utilize Cost and Value Engineering Throughout the Planning, Design, and Development Process

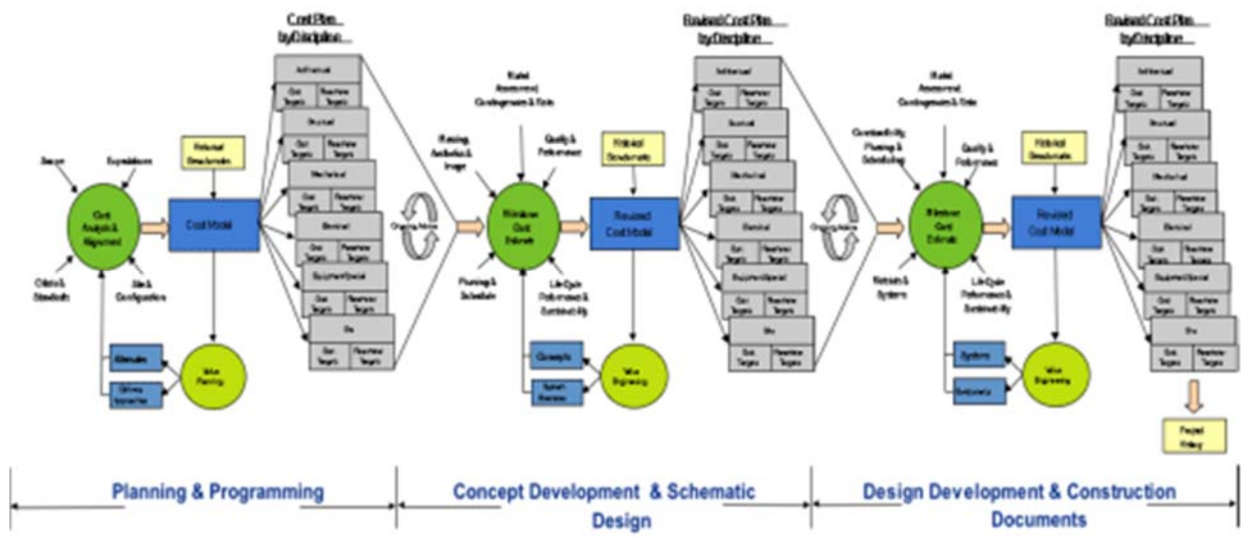
As most projects are authorized/funded without a means of increasing budgets, it is essential that the project requirements are set by considering life-cycle costs. This will ensure that the budget supports any first-cost premium that a life-cycle cost-effective alternative may incur. Once a budget has been established, it is essential to continually test the viability of its assumptions by employing cost management throughout the design and development process. An aspect of cost management is a cost control practice called *Value Engineering (VE)*. VE is a systematic evaluation procedure directed at analyzing the function of materials, systems, processes, and building equipment for the purpose of achieving required functions at the lowest total cost of ownership.

Throughout a project's planning, design, and construction phases, Cost Management is employed as a means of balancing a project's scope and expectations of quality and budget.

The approach can be summarized as requiring the following three steps:

- Define the scope, the level of quality desired, and the budget
- Ensure that the scope, quality, and budget are aligned
- Monitor and manage the balance of these three components throughout the life of the project

This process involved is represented graphically as follows:



Milestone cost estimates at various stages of the process are critical components of the cost management activity. Cost Management encompasses more than cost estimates however—it also includes Risk Management and in the federal arena, can include Earned Value Analysis. Risk Assessment and Management are important as identified risks on construction projects are typically financial in nature. Therefore early in the project an assessment of risk is crucial to establish the budget parameters within which the project must be completed.

The calculation of project contingencies should be based on an assessment of the risk surrounding the project (site issues, availability of bidders, method of procurement, and critically the market conditions in the location of the project. As risks are mitigated (site investigation is done, market survey completed, program finalized, design started, and so forth) then contingencies can be reduced and the range of estimated final cost narrowed.

The firm charged with managing the costs of the project should ideally be hired directly by the owner, early in the process, and should be independent of both the architect/engineer and the construction contractor.

Common Cost Estimator Practice Traits

Awareness

The estimator should firstly consider the project scope and the level of effort and resources needed to complete the task ahead; the organization's financial capability, staff, and plant capacity (if working as an estimator for a construction company) to complete the project.

- Consider the time allotted for the construction of the project in coordination with the owner's schedule needs.
- Examine the general and special conditions of the contract and determine the effect these requirements have on indirect costs.
- Consider alternate methods of construction for the projects.
- Review all sections of the drawings and division specifications to ascertain an accurate perspective of the total project scope, level of design discipline coordination, adequacy of details, and project constructability.
- Make other members of the project team aware of any problems with the project documents.
- Communicate and coordinate information to other project team members in a timely manner.

Uniformity

The estimator should develop a good system of estimating forms and procedures that exactly meet the requirements of the project, and that is understood and accessible by all team members. This system should provide the ability to define material, labor hour and equipment hour quantities required for the project. Material, labor, and equipment unit costs are then applied to the quantities as developed in the quantity survey. Apply amounts for overhead and profit, escalation, and contingency in the final summaries.

Consistency

Use methods for quantity surveys that are in logical order and consistent with industry standard classification systems such as the UniFormat™ or CSI MasterFormat™

systems. These methods also must meet the specific need of the company or client. Use of consistent methods allows several estimators to complete various parts of the quantity survey, or be continued later by another estimator. Consistency also aids the identification of cost increases and decreases in certain areas as the project progresses through the design stages. Combine these surveys into the final account summaries.

Verification

The method and logic employed in the quantity survey must be in a form, which can provide independent method of proof of the accuracy of any portion of the survey.

Documentation

Document all portions of the estimate in a logical, consistent, and legible manner. Estimators and other personnel may need to review the original estimate when the specific details are vague. The documentation must be clear and logical or it will be of little value to the reader. Such instances may occur in change order preparation, settlements of claims, and review of past estimates as preparation for new estimates on similar projects.

Evaluation

When the estimate involves the use of bids from subcontractors, check the bids for scope ***and responsiveness to the project. Investigate the past performance*** records ***of subcontractors submitting bids. Determine the level of competence and quality of performance.***

Labor Hours

The detailed application of labor hours to a quantity is primary in governing the accuracy and sufficiency of an estimate. The accuracy of the project's schedule and work force requirements are dependent on the evaluation and definition of the hours. The combined costs for worker's compensation, unemployment insurance and social security taxes are significant factors in the project costs. The most accurate method for including these costs is to define labor hours and wage rates; then apply percentages to the labor costs.

Value Engineering

Structure the estimate to aid in researching and developing alternative methods that will result in cost optimization. These alternative methods can include different construction methodology, replacement materials, etc. ***Using the same level of detail in both the value engineering studies and the base estimate is extremely important. This provides a more precise comparison of costs for proposed alternate methods.***

Final Summaries

Provide methods for listing and calculating indirect costs. Project scope governs the costs of overhead items such as insurance, home office plant, and ***administrative personnel. Determine these costs in a manner consistent with quantity survey applications. Consider other work in progress, and/or owner occupancy of existing space that may have*** a bearing on projected overhead costs. Determine amounts for performance bonding, profits, escalation, and contingencies.

Analysis

Develop methods for analyzing completed estimates to ascertain if they are reasonable. When the estimate is beyond the normal range of costs for similar projects, research the detail causes for possible errors.

- Develop methods of analysis of post-bid estimates to find the reasons for the lack of success in the bidding process.
- Calculate the variation of the estimate from the low bid and low average bids.
- Determine from an outside source if there were subcontract or material bids provided only to certain bidders.
- Determine if bids were submitted by a representative number of contractors for the level of construction quality expected.
- Determine if the low bidder may have made omissions in the estimate.
- Properly document this information for future use and guidance.

Conversion

Show estimating procedures that allow conversion of the estimate to field cost systems so management can monitor and control field activities. These procedures include methods of reporting field costs for problem areas. Make reports daily or weekly rather than at some point in time after the project is complete. Field cost reporting, when consistent with estimating procedures, enables estimators to apply the knowledge gained from these historical costs to future estimates, and help train field personnel in labor hour and cost reporting that provide the level of accuracy required.

Change Orders

Apply the highest level of detail from information provided or available to the estimator. State quantities and costs for all material, labor, equipment, and subcontract items of work. Define amount for overhead, profit, taxes, and bond. Specific itemization of change order proposals is essential in allowing the client to determine acceptability. Upon approval, use the estimate detail as the definition of scope of the change order.

Levels of Cost Estimate

As a project is proposed and then developed, the estimate preparation and information will change based on the needs of the Owner/Client/Designer. These changes will require estimates to be prepared at different levels during the design process with increasing degrees of information provided. It should also be noted that within each level of estimate preparation, not all portions of the design would be at the same level of completeness. For example, the architectural design may be at 80% complete while the mechanical design is only 50% complete. This is common through the design process, but should always be noted in the estimate narrative.

In addition to construction costs, estimates for process or manufacturing areas require information related to the involved processes such as product line capacity, process layout, handling requirements, utility requirements, materials and storage required, service requirements, flow diagrams, and raw materials access.

The following descriptions constitute the different levels of an estimate. Estimates within each of these levels may be prepared multiple times during the design process as more information becomes available or changes are made to the scope. As the level of the estimate increases it will become more detailed as more information is provided; "unknowns" are eliminated; fewer assumptions are made; and the pricing of the quantities become more detailed. Contingencies for the aforementioned will be reduced as more design documentation is produced.

The levels of the construction cost estimate correspond to the typical phases of the building design and development process and are considered standards within the industry. These levels are as follows:

Level 1 - Order of Magnitude

The purpose of the Level 1 estimate is to facilitate budgetary and feasibility determinations. It is prepared to develop a project budget and is based on historical information with adjustments made for specific project conditions. Estimates are based on costs per square foot, number of cars/rooms/seats, etc.

Project information required for estimates at this level usually might include a general functional description, schematic layout, geographic location, size expressed as building area, numbers of people, seats, cars, etc., and intended use.

Level 2 - Conceptual/Schematic Design

The purpose of the Level 2 estimate level is to provide a more comprehensive cost estimate to compare to the budgetary and feasibility determinations made at Level 1 and will be typically based on a better definition of the scope of work. An estimate at this level may be used to price various design schemes in order to see which scheme best fits the budget, or it may be used to price various design alternatives, or construction materials and methods for comparison.

The goal at the end of schematic design is to have a design scheme, program, and estimate that can be contained within budget. This estimate is often prepared in the UniFormat™ estimating system rather than the MasterFormat™ system, which allows the design team to easily and quickly evaluate alternative building systems and assemblies in order to make informed alternatives analysis decisions to advance the design progress. The Level 2 estimate is based on the previous level of information available at Level 1, in addition to more developed schematic design criteria such as a detailed building program, schematic drawings, sketches, renderings, diagrams, conceptual plans, elevations, sections and preliminary specifications. Information is typically supplemented with descriptions of soil and geotechnical conditions, utility requirements, foundation requirements, construction type/size determinations, and any other information that may have an impact on the estimated construction cost.

Level 3 - Design Development

Estimates prepared at Level 3 are used to verify budget conformance as the scope and design are finalized and final materials are selected. Information required for this level typically includes not less than 25% complete drawings showing floor plans, elevations, sections, typical details, preliminary schedules (finishes, partitions, doors, and hardware etc.), engineering design criteria, system single line diagrams, equipment layouts, and outline specifications.

The Level 3 estimate provides a greater amount of accuracy, made possible by better defined and detailed design documentation. Estimates at this phase may be used for value engineering applications before the completion of specifications and design drawings.

Level 4 - Construction Documents

Level 4 estimates are used to confirm funding allocations, to again verify the construction cost as design is being completed, for assessment of potential value engineering opportunities before publication of the final project design documentation for bids, and to identify any possible "design creep" items, and their costs, caused by modifications during the completion of the construction documents. This final construction document cost estimate will be used to evaluate the subcontract pricing during the bid phase. Level 4 estimates are typically based on construction documents not less than 90% complete.

Level 5 - Bid Phase

The purpose of this level estimate is to develop probable costs in the preparation and submittal of bids for contract with an Owner. In the traditional "design-bid-build" delivery system, this would be with 100% completed and coordinated documents. The Level 5 estimate will be used to evaluate sub-contractor bids and change orders during the construction process.

In other delivery systems, becoming more widely used, such as design-build or guaranteed maximum price, the bid could actually be prepared at an earlier level, often Level 3 or Level 4. In such an instance estimates are prepared as previously described along with progressive estimates as the design is completed. It should be stressed that when preparing a bid at a prior estimate level, it is very important to include a complete and thorough "Scope of Estimate" statement that would state clearly such items assumptions, allowances, documents used for the estimate, and contingency amounts included.

To explore the impact of various delivery systems on a specific project.

Various types of construction contracts include:

- Stipulated sum
- Lump sum unit price
- Cost plus a fee
- Design-build
- Bridging
- Cost plus a fee with a guaranteed maximum price (GMP)
- Turn Key

The transfer of the estimate information to the field cost control system provides management the opportunity to closely monitor and control construction costs as they occur. Computer estimating and cost control programs, whether industry-specific or general spreadsheet type, are especially valuable for rapid and efficient generation of both the estimate and actual construction cost information.

It should be noted that it is always good cost control practice to review and evaluate the final cost estimate vs. the actual bid. This exercise is not another level of estimate, but is a cost control mechanism and important data for estimating future projects.

Elements of a Cost Estimate

Quantity Takeoff

The foundation for a successful estimate relies upon reliable identification (takeoff) of the quantities of the various materials involved in the project.

Labor Hours

Labor hour amounts can be developed by crew analysis or applied on a unit man-hour basis. The use of a labor dollar per unit of work (ex: $15 per cubic yard for grade beams or $20 per cubic yard for walls) is only applicable when the cost history supports the data being used. The estimator must make allowance for the varying production capability that will occur based upon the complexity of a project.

Labor Rates

The labor rate is the cost per hour for the craftsmen on the project. To determine any craft rate, whether union or open shop, the estimator starts with the basic wages and fringe benefits.

- To the wages and fringe benefits, the estimator must add payroll burdens. These are FICA (Social Security), FUI (Federal Unemployment Insurance), SUI (State Unemployment Insurance), WC (Worker Compensation) and others mandated by legislation and/or company operations. These burdens, plus the base wages and fringe benefits, determine the hourly cost of a craft classification (i.e., carpenter, pipefitter, etc.).
- The hourly rate can also involve a mixed crew where a mix of different crafts for a work crew for the performance of the work.
- Overtime or the lack of overtime is another consideration in determining the calculation of the hourly rates. A project that is scheduled for completion using a forty hour work week (Some areas may have a standard 35 hour week) will have a modest amount of overtime costs required in the estimate. A project that is scheduled for extended 50, 60 or even 70 hour work weeks will have a substantial amount included for overtime and loss of productivity.

Material Prices

Material prices, especially in today's current market, fluctuate up and down. The estimator must both understand and anticipate the frequency and extent of the price variations and the timing of the buying cycle. Material prices may be affected by:

- purchase at a peak or slack time of the year for the manufacturer
- material availability
- the size of the order
- the delivery timeframe requirement
- physical requirements for delivery, such as distance, road size, or site access
- payment terms and history on previous purchases
- sole-source items
- exchange rates (if the material will be imported)

Equipment Costs

Equipment rates depend on the project conditions to determine the correct size or capacity of equipment required to perform the work. When interfacing with other equipment, cycle times and equipment capacity control the costs on the project. Costs will also differ if the equipment is owned by the contractor as opposed to rented.

Subcontractor Quotes

A subcontractor quote, like the general estimate, contains labor, material, equipment, indirect costs, and profit. It is dependent upon having the quantities, labor hours, hourly rate, etc., prepared in a reliable manner just like any other part of an estimate. The amount of the subcontractor quote is also dependent upon the payment terms of the contract, and previous payment history between the subcontractor and general contractor. Bonding costs should also be considered.

Indirect Costs

Indirect costs consist of labor, material, and equipment items required to support the overall project.

For the owner: design fees, permits, land acquisition costs, legal fees, administration costs, etc.

For the contractor and subcontractor: mobilization, staffing, on-site job office, temporary construction, temporary heat/cooling, and temporary utilities, equipment, small tools and consumables, etc.

Profit Amount

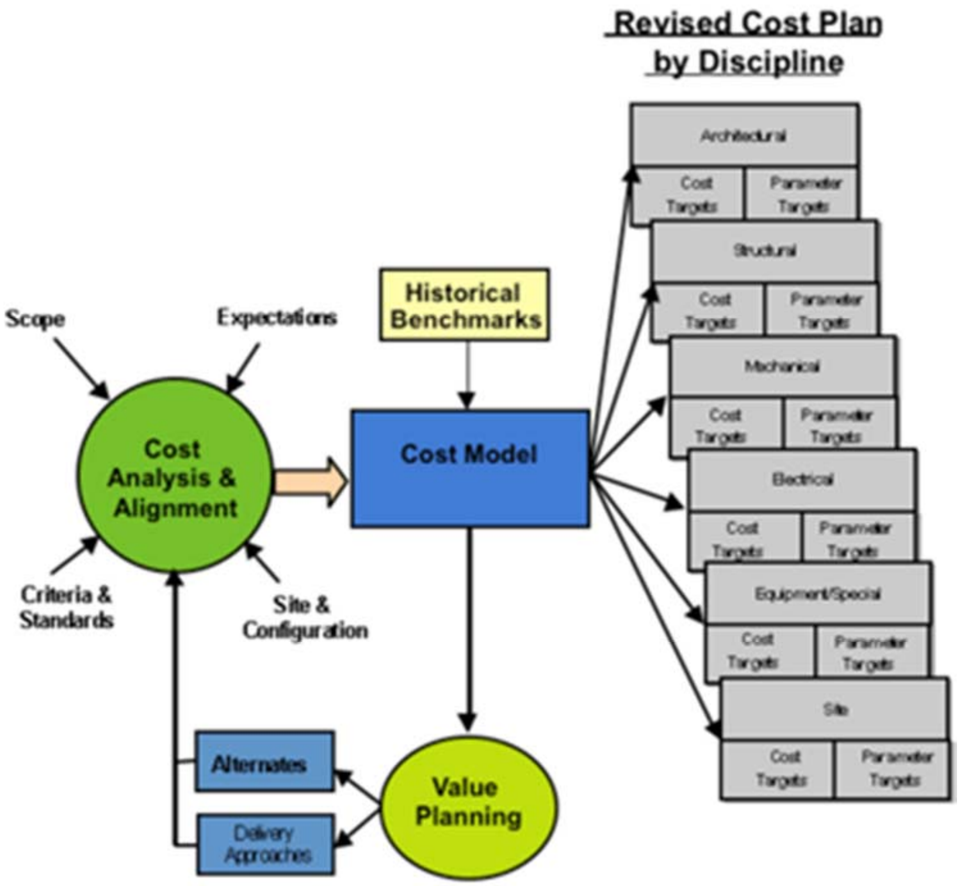
Apply appropriate or contracted profit rate uniformly to all contractors and to original bid and change orders.

Planning Phase

Cost Management differs from Building Economics in that it is typically concerned with the initial costs—or first costs—of accomplishing new construction or renovation projects. A project must start right in order for it to finish right, so the establishment of an appropriate budget is critical. Early in the planning stages, both building owners and designers must agree on an anticipated cost of the project at bid award.

This is a critical stage in the cost management process—an inaccurate budget can doom a project to continual stress and compromise, with neither the owner, end-user, nor design team being completely satisfied at the end. A common mistake at this stage is to take a program of areas and apply those to historical costs without making adjustments for the myriad factors which affect construction costs—size of the project, renovation versus new, location (has a market survey been done?), price increases since the date of the data used, method of procurement, overall quality of the space envisioned, LEED rating desired if any, access and locational factors such as dense urban, traffic and sidewalk protection, water location, bid competitiveness in the local market, etc.

Preliminary Estimates are employed in the early planning phases of a proposed project to match an owner's needs, expressed as written programmatic requirements, with budget constraints in order to establish its overall scope (size) and quality expectations.



Planning & Programming

The proposed method of procurement, or delivery approach in the above graphic, should be identified at this stage.

The options available today are more numerous than in the past—traditional Lump Sum, Construction Manager as Constructor (CMC) (also known as CM at Risk), Design/Build, Integrated Project Delivery (IPD) and so forth. Each method has pros and cons relative to cost and risk, so the method selected should also be factored in to the project budget.

These can generally be summarized as follows:

Traditional Design-Bid-Build		
Issues	**Advantages**	**Disadvantages**
Cost and Budget Management	"Best price" potential Perception of "best price"	Cost not finalized until bids

		Cost overruns after bid require expensive redesign Bidders may seek to "get low" by omitting work not clearly shown
Schedule Impact and Management	Delivery schedule stipulated in contract	Construction difficult to start before design is finished Extended/compressed schedules may add cost & not be evident Schedule changes after award difficult to implement

Construction Manager at Risk		
Issues	**Advantages**	**Disadvantages**
Cost and Budget Management	Cost "guarantee" prior to design completion Improved perception of control Cost saving incentives are feasible	After GMP, costs may increase due to detailing not correctly reflected in the GMP CM may "expand" budget to create opportunity for future "savings"
Schedule Impact and Management	Construction can start before design is complete Cost impact of extended/compressed schedule can be addressed prior to GMP	Schedule changes during construction difficult to implement

Design-Build		
Issues	**Advantages**	**Disadvantages**
Cost and Budget Management	Early cost guarantee Price tends to match quality Can obtain best price for performance	Fair price competition difficult to verify Cost impact of risk issues may not be evident in initial pricing Owner over-emphasis on price as a selection criteria may force the design-builder to compromise quality to reduce price
Schedule Impact and Management	Construction can start after very preliminary design Generally considered as most beneficial schedule approach	Schedule changes at any point after pricing difficult to implement Use of "bridging" type approach may expand schedule

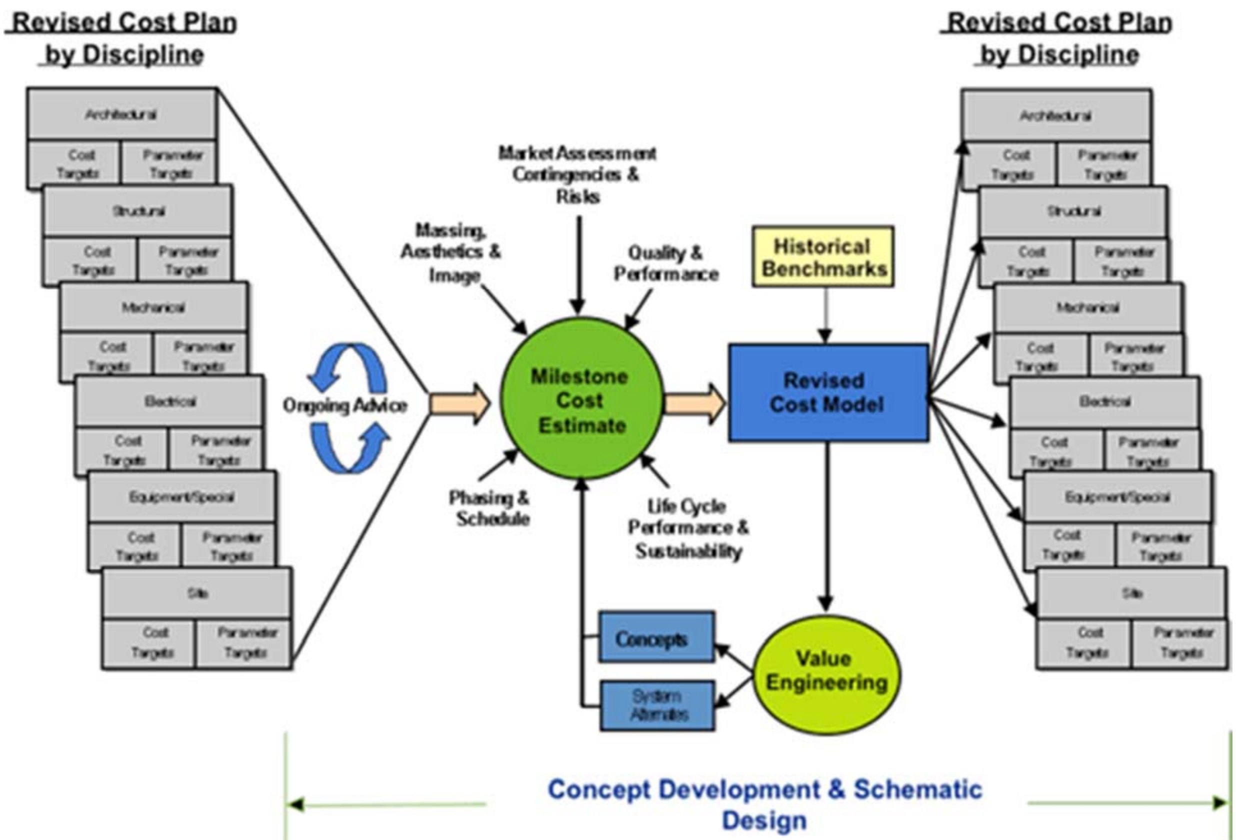
Integrated Project Delivery as a procurement method is gaining some traction in the industry, although it still only is used on 1–2% of projects and legal difficulties around liability remain a hurdle for broader acceptance. From a cost management perspective the benefits remain elusive as the various parties on the team generally have differing objectives, although doubtless the coordination of the trades and cohesiveness of the design may impart some time savings and reduced change orders during construction. The use of Building Information Modeling (BIM) is likewise a growing trend and from an owner's perspective a very useful tool, with similar benefits to IPD but few documented advantages related to cost management. While the technology is improving, the quality of estimates produced from BIM models is still fairly uneven. Quantity take-offs are becoming more accurate (although still highly dependent on the accuracy of the data entered into the model) but the pricing aspects and the capture of components not yet in the model still require considerable scrutiny by the cost estimator.

Value Engineering should also be considered at this stage. Any changes to the program at this early phase have very little, if any, impact on schedule and A/E time and redesign costs, but the benefits in terms of solidifying the program and establishing project goals can be huge.

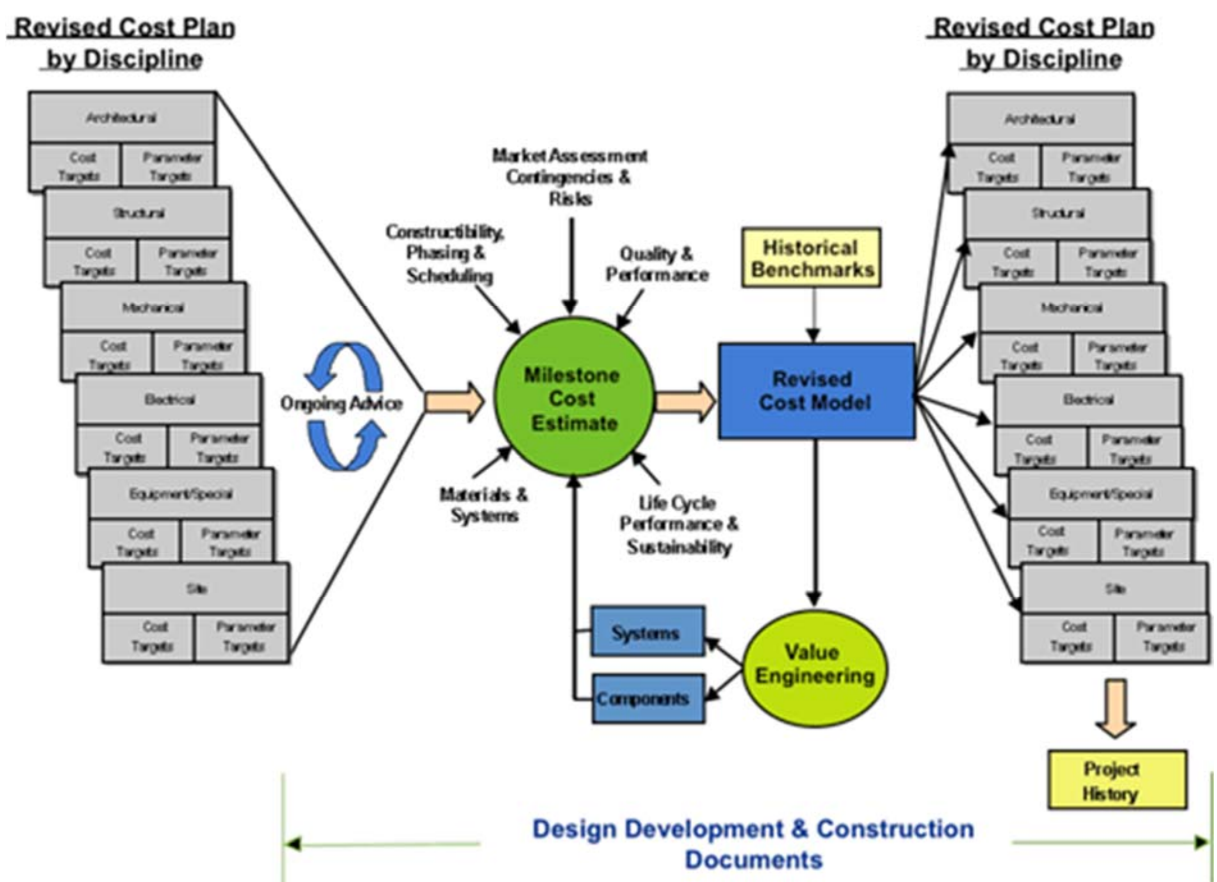
Design Phase

Chesapeake Bay Foundation Philip Merrill Environmental Center—Annapolis, MD

Once an initial budget has been established, the scope set and the quality expectations documented, it is important to monitor the estimated cost of the project by employing a series of increasingly precise cost estimating techniques that coincide with further development of design and construction details.



Intermediate estimates are employed at various stages of project design development as part of ongoing cost management, and as a means of evaluating competing alternative construction assemblies, systems, and materials. On large projects it is common practice for an owner to employ a construction manager or professional estimator to continually update project estimates and provide feedback on budget impacts of decisions on major design elements. The drawings and specifications should also go through a constructability review, wherein an independent review team analyzes the construction documents for completeness, coordination between disciplines, cost-effective design solutions, and general code compliance (as mentioned earlier this is where BIM and IPD bring significant benefits). The specifications should also be reviewed to ensure that the General Requirements included in division 1 are not overly restrictive (e.g. working hours, noise restrictions and so forth) and that throughout the specifications the use of proprietary materials is minimized. A market survey should have been carried out on sizable projects to determine where the bidders will come from—is the local market sufficiently large to accommodate the project, or will the major subcontractors be at capacity and therefore likely to bid high, if at all? It's often worth re-verifying the market survey if one was done much earlier in the process.



The estimates become much more refined in parallel with the refinement of the design, ultimately resulting in a pre-bid estimate that captures the entirety of the project.

Earned Value Analysis is a useful tool in cost management, in that costs for each component of the project (in a Work Breakdown Structure, or WBS) can be tracked against the initial budget, and adjustments made to ensure the overall budget is on track. Movements between components are common; however, without tracking where costs are changing, the budget is in danger of being exceeded leading to re-design or extensive value engineering. Similarly future cost planning can be improved by the use of Earned Value Analysis, by tracking where the money really goes in a project.

Procurement Phase

At the bid stage, the drawings should be 100% complete; however, in many instances this does not happen, leading to addenda being issued to clarify details, resolve conflicts or to complete the design. Often the estimate is not adjusted to account for these design changes, leading to a so-called final estimate that really does not represent the scope of work being bid.

The estimate should therefore be adjusted during bidding to reflect the same information the bidders receive. Also a read of the market at bid stage is still useful, and can be included in a risk assessment to determine a range of bids expected. In a particularly volatile market, the use of bid options may allow the owner some flexibility in achieving the budget on bid day.

The preparation of the bidding documents is also crucial in an overall cost management strategy. Consideration should be given to contract clauses that govern changes in the work and how they will be valued (e.g. by reference to a published price book or trade manual); allowable mark-ups on changes by the various levels of contractors and sub-contractors; notice requirements for delays; the use of unit prices for changes and any other clauses that may affect the final cost of the project.

Construction Phase

During construction the focus shifts from predictive cost estimating to reactive cost management of any changes in the work. Changes arise from a number of different sources—unforeseen conditions, owner-generated changes, drawing errors and omissions, code issues or contractual claims.

Also changes can arise from on-going proactive cost management, either generated by the design team or the general contractor, where one of the parties proposes a better-value substitution (sometimes known as Value Engineering Change Proposals or VECPs).

For all reviews of changes the owner should first establish the ground rules as delineated in the contract documents, agree a format with the general contractor, and require the general contractor to first review change proposal from subcontractors before compiling and forwarding to the owner.

Changes should also be reviewed by the design team for entitlement—is it really a change to the scope and are there any credits due? Then the agency Construction Manager or independent cost consultant should review the pricing against the contract and industry norms, leading to an independent government estimate for presentation to the general contractor. Wherever possible the value of the change should be agreed before the work is installed, otherwise the owner's leverage to agree a fair and reasonable price is greatly diminished.

Facility Performance Evaluation

To provide data for future cost management, an evaluation is often carried out to prepare a detailed cost analysis of the completed project and to develop lessons learned to inform future design decisions. The cost data captured should also be fed back in to the owner's database to better inform future estimates and budgets. Other areas to consider here include a review of energy performance of the building during occupancy, to ascertain if the data used as the basis for selection of the mechanical and electrical systems and components was accurate vis-a-vis the actual performance.

2. Use Economic Analysis to Evaluate Design Alternatives

In addition to first costs, facility investment decisions typically include projected cost impacts of, energy/utility use, operation and maintenance and future system replacements. At the beginning of each project, establish what economic tools and models will be used to evaluate these building investment parameters. The methodologies of life-cycle cost analysis (LCCA) will typically offer comparisons of total life-cycle costs based upon net present values. Other methods usually used as supplementary measures of cost-effectiveness to the LCCA include Net Savings, Savings-to-Investment Ratios, Internal Rate of Return, and Payback.

Formally defined, economic analysis is the monetary evaluation of alternatives for meeting a given objective. For example, to meet the need for additional office space a decision maker might consider new construction, renovating an existing facility, or leasing another building. The evaluation is based on a comparison of discounted costs and benefits over a fixed time period of time. Alternatives can be summarized in terms of the ratio of total benefits to total cost (benefit-cost ratio) or equivalently, the total net benefits (net present value).

The Economic Analysis Process

The steps to estimate the economic consequences of a decision, as listed in Ruegg's and Marshall's *Building Economics—Theory and Practice*, are summarized below:

- Define the problem and the objective.
- Identify feasible alternatives for accomplishing the objective, taking into account any constraints.
- Determine whether an economic analysis is necessary, and if so, the level of effort which is warranted.
- Select a method or methods of economic analysis.
- Select a technique that accounts for uncertainty and/or risk if the data to be used with the economic method are uncertain.
- Compile data and make assumptions called for by the economic analysis method(s) and risk analysis technique.
- Compute a measure of economic performance.
- Compare the economic consequences of alternatives and make a decision, taking into account any non-quantified effects and the risk attitude of the decision maker.

Types of Economic Analysis Methods

The process described above is cost-benefit analysis, and is appropriate where both the costs and benefits can differ among alternatives. When the benefits are equivalent, the evaluation of alternatives is simplified to a cost comparison, or cost- effectiveness analysis.

Life-Cycle Cost Analysis

the photo to the right for the solar photovoltaic system, cool roofing, and energy efficiency upgrades installed at Alameda County's Santa Rita Jail have resulted in net savings of $410,000 in its first year of operation.

Life-Cycle Cost Analysis (LCCA) is a type of cost-effectiveness study common in the comparison of building projects for the evaluation of energy and water conservation measures.

Life cycle costs can include all costs of building ownership over its service life, including construction, maintenance & operation, recapitalization, and disposal. Alternatives can be evaluated on the basis of discounted total cost, or the net savings relative to a "do nothing" alternative such as the savings-to-investment ratio, internal rate of return, or time to payback.

Value Engineering

Value Engineering is a systematic evaluation procedure directed at analyzing the function of materials, systems, processes, and building equipment for the purpose of achieving required functions at the lowest total cost of ownership.

According to VE experts Kirk and Dell'Isola, "Value Engineering is a team approach that analyzes a function by systematically developing the answers to such questions as: what is it?; what does it do?; what must it do?; what does it cost?; what other material or method could be used to do the same job without sacrificing required performance or degradation to safety, reliability, or maintainability?" VE is concerned with elimination or modification of anything that adds costs without contributing to the program functional requirements. Reductions in a project's scope or quality to get it into budget are not considered VE—those decisions are simply "cost cutting".

Major public works projects may undergo both VE studies and LCCA, and while the two practices serve separate purposes, their consideration of design alternatives is often interrelated. For example, value engineering can be used to complement a life-cycle cost analysis when selected LCC alternatives cannot be adopted without exceeding the project budget. VE can be utilized to reduce initial costs of design features other than those under study in a LCCA. If the VE effort results in sufficient reduction in initial costs, savings may allow selected LCC alternatives to be adopted within the overall program budget, thus optimizing the long-term cost-effectiveness of the project as a whole.

Limits of Economic Analysis

Perhaps the most challenging aspect of economic analysis is identifying those benefits and costs that resist quantification.

These typically include aesthetics, safety, environmental impact, historic preservation.

Sensitivity analysis should be considered when running the numbers and evaluating alternatives. Effects of discount rates, escalation rates, utility costs, etc., can be overlooked. A rigorous sensitivity analysis can help establish which factors are most important in the life cycle analysis and accurate impacts on the decision-making.

3. Consider Non-Monetary Benefits such as Aesthetics, Historic Preservation, Security, and Safety

Most economic models require analysts to place a dollar value on all aspects of a design to generate final results. Nevertheless it is difficult to accurately value certain non-monetary building attributes, such as formality (for example, of a federal courthouse) or energy security. The objective of a LCCA is to determine costs *and* benefits of design alternatives to facilitate informed decision-making.

Costs can be more readily quantified than benefits because they normally have dollar amounts attached. Benefits are difficult because they often tend to have more intangibles. In some cases, these non-monetary issues are used as tiebreakers to quantitative analyses. In other instances, non-monetary issues can override quantitatively available cost comparisons, for example, renewable energy application.

These cost-effectiveness principles serve as driving objectives for cost management practices in the planning, design, construction, and operation of facilities that balance cost, scope, and quality. Analyzing the environmental costs through Life Cycle Assessment (LCA) can be complementary to the dollar cost implications of the design, materials selection, and operation of buildings.

The LCA methodology, which can enhance information gleaned from an LCC, includes definition of goal and scope, an inventory assessment, life-cycle impact assessment, and interpretation-an iterative process.

The essential aspects of conducting a life-cycle cost analysis (LCCA) and determining the cost-effectiveness of any given construction alternative are the identification of all the relevant *inputs* and *outputs* and quantification, when possible, of these as *costs* and *benefits* to facilitate informed decision making. Costs can be more readily quantified than benefits because they normally have dollar amounts attached. Benefits are difficult because they often tend to have more intangibles. In analyses, benefits should be as important as costs and deserve to be brought to the attention of decision makers.

Other Quantifiable Benefits

Many investment decisions, especially in industrial applications, have a stated goal defined in terms of required or expected output (e.g. number of kilowatt-hours of electricity produced per year, number of aircraft overhauled per year). The goal is not always quantified, but it is often susceptible to quantification and thus provides a potential measure of benefits associated with the investment. Benefit may be determined when the output from the investment can be quantified and a uniform annual cost derived from the life-cycle cost analysis (LCCA). Using the examples provided, typical output of this type would be number of kilowatt-hours of electricity produced (benefit) or completed aircraft overhauls (benefit) per $1,000 (cost). These ratios may be compared for several different alternatives to assist in selection of the most cost-effective.

Non-Quantifiable Benefits

Despite best efforts to develop quantitative measures of benefits, there are situations that simply do not lend themselves to such an analysis. Certain projects may provide benefits such as improved quality of the working environment, preservation of cultural and historical resources, safety and security of the building occupants, and other similar qualitative advantages. Although they are most difficult to assess, these benefits should be documented and portrayed in a life-cycle cost analysis.

Owners of the West Bend Mutual Insurance credited the energy efficient strategies implemented in the new Headquarters Building, West Bend, IN for 99% reduction in personnel complaints about IAQ and 16% improvement in productivity.

In such instances, written and accurate descriptions of qualitative benefits must be done. This is the least preferred method of analyzing benefits due to its subjectivity and inherent lack of precision. However, under certain conditions, this method must suffice; and if the following guidelines are observed, qualitative statements can make a positive contribution to the analysis.

- Identify all benefits associated with each alternative under consideration. Give complete details.
- Identify the benefits common in kind but not to the same degree among the alternatives. Explain all differences in detail.

To formalize the inclusion of non-monetary costs or benefits in the decision-making process, the analytical hierarchy process (AHP) should be employed. AHP is one of a set of multi-attribute decision analysis (MADA) methods that consider non-monetary attributes (qualitative and quantitative) in addition to common economic evaluation measures when evaluating project alternatives.

System published by ASTM International presents a procedure for calculating and interpreting AHP scores of a project's total overall desirability when making building-related capital investment decisions.

Following these general guidelines will help to enhance the difficult task of documenting these intangibles that are measured in non-economic terms like aesthetics, safety, or morale, and enhance the value of benefit/cost analyses and make informed decision-making easier.

Quantifying Negative Aspects

It is also noted that in addition to benefits, information concerning negative aspects of alternatives, quantified where possible, should also be included to ensure the objectivity and completeness of the analysis. This information is important in decision making and possibly to the community at large; and may be a determining factor in deciding between possible investments alternatives.

Externalities

Externalities (also referred to as external effects or spillovers) are an important class of outputs that may be benefits or disadvantages. They are generally defined as outputs involuntarily received or imposed on a person or group because of an action by another and over which the recipient has no control. Air pollution is an example of an externality that is not a benefit. The recipients accrue potential health, aesthetic, and other disadvantages from a polluter for which they receive no compensation.

For most investment decisions (particularly with respect to the public sector), it is not necessary to analyze in depth externalities such as environmental impacts and community economic impacts as part of the life-cycle cost analysis. These aspects of alternatives being considered are usually treated in detail as part of the Environmental Impact Assessment/Environmental Impact Statement process or environmental documentation associated with local and state processes for addressing environmental impacts of construction projects. However, the mention of anticipated impacts (both quantified and qualitative) in life-cycle cost analysis documentation is appropriate.

Summary

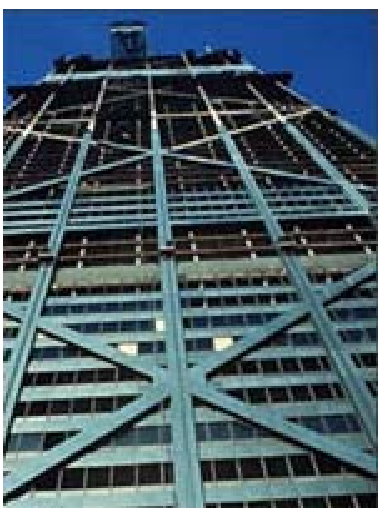
There is no standard or recommended format prescribed for benefit analysis information. What is important is the content; and in the case of benefits, content is critical. No analysis is truly complete unless it addresses benefits attending all the alternatives under consideration.

Functional / Operational

OVERVIEW

A clear understanding of the functional and physical requirements of a project is essential to ensuring its success. A client's / owner's intent to develop a project is derived from a need, a purpose or mission, and a desired result. When the design of a facility satisfies the emotional, cognitive, and cultural needs of the people who use it and the technical requisites of the programs it houses, the project is functionally successful.

Program and functionality are also characterized by building type. A building that functions as it is intended is the underpinning of a quality "whole" building. The qualities of such a building may not even be noticed or recognized, but a poorly functioning building can be costly to correct, if the opportunity to correct ever becomes available. When designs fall short of this goal, the cost can be modest to extreme, but the failures are generally noted more significantly than the expected successes.



Left: Exterior lateral bracing created open interior spaces at the John Hancock Building—Chicago, IL

Right: CalPERs Headquarters Complex day lit interior atrium space in the building's core

Development in the building sciences in the late 1900's has pointed to the need to refocus on programming, designing, constructing, and operating facilities that function well, while at the same time incorporating new technologies, and creatively meeting other design objectives: sustainability, accessibility, safety, aesthetics, cost effectiveness, productivity, and historic preservation.

Addressing these design objectives while achieving energy savings, and improving environmental quality is paramount in designing the "whole" building. Facility Performance Evaluations have shown that early programming and design decisions have significant impact on the functional quality, and long-term efficiency and effectiveness of buildings, initially and over their life cycle, such as:

1. Adaptability: decisions at the inception of project design to incorporate elements and concepts that will assist with future adaptations to a building can facilitate change in the future:
    - Building to readily facilitate horizontal and vertical expansion
    - Analyzing the building structural concept, i.e. structural grid, dimensions, and floor-to-floor heights that allow for flexibility in internal layouts
2. Functional Quality: decisions to incorporate the use of hard walls for offices and workspaces vs. flexible 'furniture' systems have a significant impact on functionality of a building.

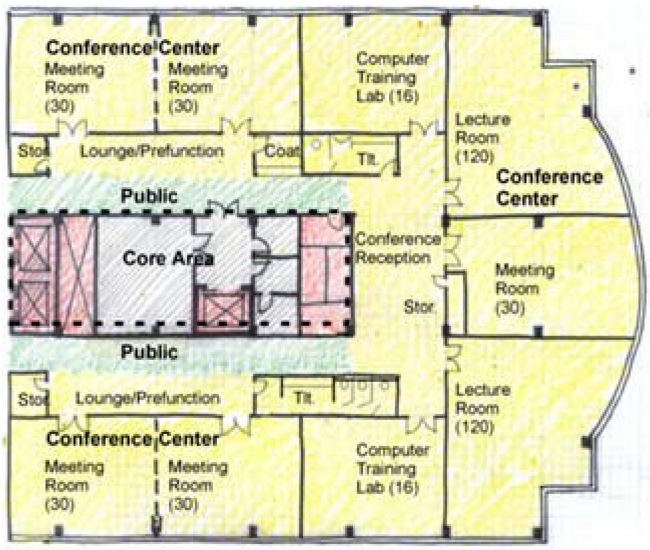
Adopting an integrated design approach and quality assurance processes that extend through all of the phases of design and construction of a project, from pre-design through owner occupancy and operation, with checks at each stage of the process will help ensure validation of decisions to meet the owner's program and design requirements. Buildings that are more functionally successful also create more inspiring, safe, and productive environments that enhance work and/or livability.

A building is considered to perform at a high level when all key design objectives are considered from the early project development phase, rather than focusing on one design objective while others are trivialized or overlooked all together. For example, most projects have both security goals that must be met. Discussing these early on can help ensure a project's functionality goals are met as well as its productivity goals. The ability to buildings can also help achieve the functional and productive goals of the project.

There are three overarching principles associated with ensuring functional building design and operations:

1. **Account for Functional and Psychological Needs**

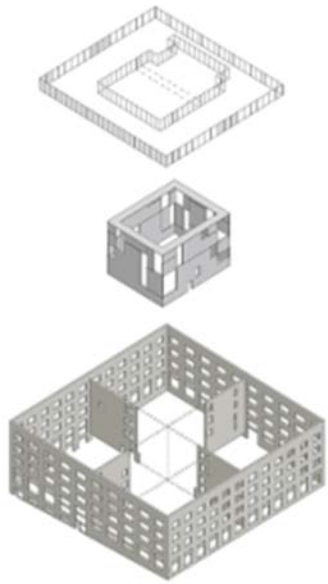
Identifying the spatial requirements and psychological needs developed in the functional program is a primary element of the planning process that translates to an owner's spatial and service requirements for a building or facility. Key tasks in this process are: problem definition or statement, establishing goals, collecting and analyzing facts, establishing functional relationships, and uncovering and testing concepts. There is also a need to flexibility of programmed space.



Conference Space Type

Programming should begin with a clear definition of the activities to be performed and the people who will use the space. Accounting for functional and psychological needs is a primary purpose of the planning process that defines an owner's functional and physical requirements for each spatial element in a building or facility. This process seeks to:

- state the problem;
- establish goals;
- collect and analyze facts;
- establish functional relationships;
- uncover and test concepts;
- state the problem to direct a course of action.



Primary Systems diagram of the Wieden + Kennedy Ad Agency building—Portland, OR Courtesy of Allied Works Architecture

Adequate programming performed in the project planning phase will clearly delineate in-use requirements and relationships of occupant activities and spaces required for all supporting building systems and equipment. Effective programming will include all pertinent stakeholders to identify that all "Whole Building" functions and needs have been identified. Conducting programming and design charrettes with these stakeholders is an effective means of enhancing integrated functionality and mutual agreement on a design approach.

However, a truly functional building will require a thorough analysis of the parts of the design problem and the application of creative synthesis in a solution that integrates the parts in a coherent and optimal operating manner. 'Whole Building' design is characterized by a design solution that functions well from an occupant activity and building systems point of view.

There are several key steps in the development of project requirements that fully describe the design problem. They are:

- Understand how the work processes support the mission and purpose of a facility;
- Define spatial requirements for occupant activities and equipment in a Space Program;
- Understand functional relationships among the programmed spaces;
- Anticipate installation, Operations & Maintenance (O&M) practices, spatial change, and replacement of building equipment;

- Accommodate information technology (IT), communication, and other building systems equipment; and
- Consider serviceability (clearance) requirements.

RECOMMENDATIONS

- Understand How the Functional Needs Support the Mission and Purpose of a Facility
- Determine facility use, occupancy, and activities to be housed.
- Consider the functional needs in the context of all the other design objectives to ensure a balanced and integrated design.
- Balance the owners and users' needs and goals for space, quality, budget, and time.
- Set owner's design objectives in the early planning stage.
- Reference building type guidelines.
- Look beyond the facility to understand the role the site plays in meeting the functional needs in support of the mission and purpose of a facility.
- Define Spatial Requirements for Occupant Activities and Equipment
- Consult all pertinent stakeholders for their requirements.
- Consult planning guides and specialists on programmed activities equipment.
- Document all regulatory requirements, such as building codes, accessibility laws, anti-terrorism/force protection (ATFP), etc.
- Explore the possible necessity of making spaces flexible to accommodate changes in business practices, work activities, and technologies.
- Consider building operations and maintenance activities in the defining of space requirements.
- Look beyond the facility to understand the role the site/landscape plays in defining spatial requirements for occupant activities and equipment.
- Understand Functional Relationships Between Program Spaces
- Engage user groups in discussions to brainstorm functional relationship solutions.
- Examine patterns of activity in facility programs and consider how those patterns create spatial relationships.

Vontz Center for Molecular Studies—Cincinnati, Ohio. This 150,000 gsf. $35 million interdisciplinary research center is designed to accommodate neuroscience and cancer research. It includes core science research labs, offices, support areas, and seminar rooms with fully accessible mechanical, electrical, and support spaces between the main laboratory floors.

- Account for physical security requirements in the layout of space planning.
- Consider impacts of building systems and engineering needs on spatial relationships in indoor and outdoor occupied and unoccupied spaces.
- Leverage opportunities to consider quality environmental elements such as: natural light, spatial volume, views, connection to the landscape and nature, texture, and materials.
- Look beyond the facility to understand the role the site/landscape plays in the functional relationship between spaces.
- Anticipate Installation, Operation, Spatial Change, Reuse, and Replacement of Building and Equipment
- Incorporate infrastructure system needs (structural, electrical, plumbing, and mechanical systems) as integral parts of early design concepts.
- Account for structural loads (dead and live) of building systems and equipment.
- Ensure that all building system equipment and furniture, fixtures, and building equipment (FF&E) can actually be installed, operated, and replaced.
- Consult facility O&M personnel in the programming and early design stage.
- Plan infrastructure for flexible spatial modifications or "churn" and repurposing of the building in the future.
- Accommodate Information Technology (IT), Communication, and Other Building Systems Equipment

- Determine the owner's goals and needs for spatial and mechanical support of the organization's IT program.
- Incorporate IT system needs as an integral part of the design concept.
- Design for configuration flexibility within workspaces that promotes occupant productivity.
- Accommodate network support and servicing requirements in the design of spaces.
- Consider Serviceability (Clearance) Requirements
- Design for vehicular clearances in the site design (e.g., drives, gates, ramps, parking).
- Design for vehicular clearances in building design (e.g., doors, docks, obstructions).
- Design for proper equipment access for maintenance and removal and replacement of equipment and/or major components, such as filters, boiler tubes or piping.
- Design for equipment and system life cycle.
- Design for maintainability (including housing of maintenance equipment).
- Consult facility O&M personnel in the design process.

2. Ensure Appropriate Product / Systems Integration

A successfully designed building that functions properly in all respects is composed of building systems, materials, and technologies that are selected and integrated to be mutually supportive as a cohesive "whole" system.

"There is no separation of utility and beauty. You cannot determine where a tree stops being beautiful and starts becoming utilitarian." Richard Neutra

A successfully designed building has been compared to a beautiful symphony. The parts of a building, like individual instruments in an orchestra, have the capacity to make up a whole that is greater than if they were played alone.

Imagine, for instance, that a space had a beautifully designed interior and state-of-the-art furniture and computer equipment, but could not be heated and cooled properly. The lack of adequate climate control would be as apparent as if a loud "off-key" note were played during a symphony.

Centre Georges Pompidou in Paris, France was designed by Italian architect Renzo Piano, British architect Richard Rogers, and Italian architect Gianfranco Franchini and completed in 1977. It was a bold change in design to expose a skeleton of brightly colored tubes for mechanical systems on the building's exterior. Courtesy of Rogers and Piano

Like musical instruments, building systems, materials, and products incorporated into a design must be "integrated" in a supporting way to create a unified whole that achieves the desired functional purpose.

An integrated solution results from a methodical design approach that considers the characteristics and properties of each system or product, its role in the greater whole of the design, and its needs for installation, coordination with other building systems and O&M serviceability. For example, the selection of a ceiling light fixture has implications that must be considered in terms of light as well as energy, heat, noise, and radiation. An integrated design team will:

- Develop design concepts that meet functional needs of the building program;
- Understand the integral relationship of form and function;
- Evaluate product/system selection for the specific application;
- Seek design solutions that fully integrate product/systems; and
- Consider how the facility will be operated and maintained.

Davies Symphony Hall in San Francisco, was collaboratively designed by architects and acousticians to create an auditorium that allows sound to rise to its very top, this modern but warm space captures and diffuses music throughout the audience, creating an intimate setting that belies the stature of the building itself.

RECOMMENDATIONS

- Develop Design Concepts that Meet Functional Needs of the Building Program
- Understand the full-range of needs (e.g., cognitive, emotional, and cultural) of occupants required to perform programmed activities (space, environmental qualities, furniture, fixtures, equipment, communications, information technologies, etc.).
- Explore a variety of design solutions and consider the merits of each alternative on the basis of functional performance.
- Facilitate discussions with users to evaluate and test assumptions made involving functional issues.
- Understand design implications and space needs of unique "mission critical" activities requiring permanent construction as compared to more flexible spaces that can be configured to support multiple activities and functions.
- Track decisions to maintain focus on design intents.

- Understand the Integral Relationship Between Form and Function

Chesapeake Bay Foundation's John Philip Merrill Environmental Center—Annapolis, MD. The glazed wall on the south contributes to passive solar heating and daylighting. The need for sun control resulted in an interior shading system that mimics sailboat rigging and an external structure supporting a "Brise Soleil", or solar shades. Courtesy of David Harp/Chesapeake Bay Foundation

- Accept environmental conditions as a significant influence on the building's form.
- Develop design concepts that provide the user with a clear sense of the facility's functional purpose.
- Use product/systems integration to support functional requirements and aesthetic goals.
- Evaluate Product/System Selection for the Specific Application
- Select systems and products that are "use-and user-appropriate" and support functional and psychological goals of individual spaces as well as the entire facility.
- Avoid a "one size fits all" design approach.
- Look at design problems as unique opportunities for creativity and innovation in the selection of products and systems.
- When resolving conflicts in the design and selection of products and systems, coordinate with consideration of opportunities and impacts affecting design and constructability of all involved building systems.
- Consider energy conservation and Life-Cycle Cost Analysis in the selection of products and systems especially for facilities with longer expected/designed service life (such as institutional and governmental buildings).
- Seek Integrated Design Solutions that Fully Incorporate Product/Systems
- Integrated design strikes a balance between all design objectives, including Aesthetics, Functional and the integration of products and systems.

- Adopt a 'Whole Buildings' approach—Systems integration involves the awareness of all affected trades and disciplines. Design with functional attributes of systems and products in mind.
- Select materials and products that are compatible with design objectives for both appearance and function.
- Carefully research the owner's equipment requirements and integrate them with the design.
- Consider How the Facility Will Be Operated and Maintained
- Anticipate the needs of the building-cleaning program, including refuse storage and disposal.
- Provide adequate space for maintenance equipment, materials, and storage.
- Design for regular building systems maintenance, including easy access to light fixtures, HVAC filters, sensors, and surfaces requiring scheduled cleaning.
- Plan for eventual replacement of major systems components.
- Give careful thought to designing delivery drives, loading docks, and storage rooms. Allow ample maneuvering room and clearance width and height.

3. Meet Performance Objectives

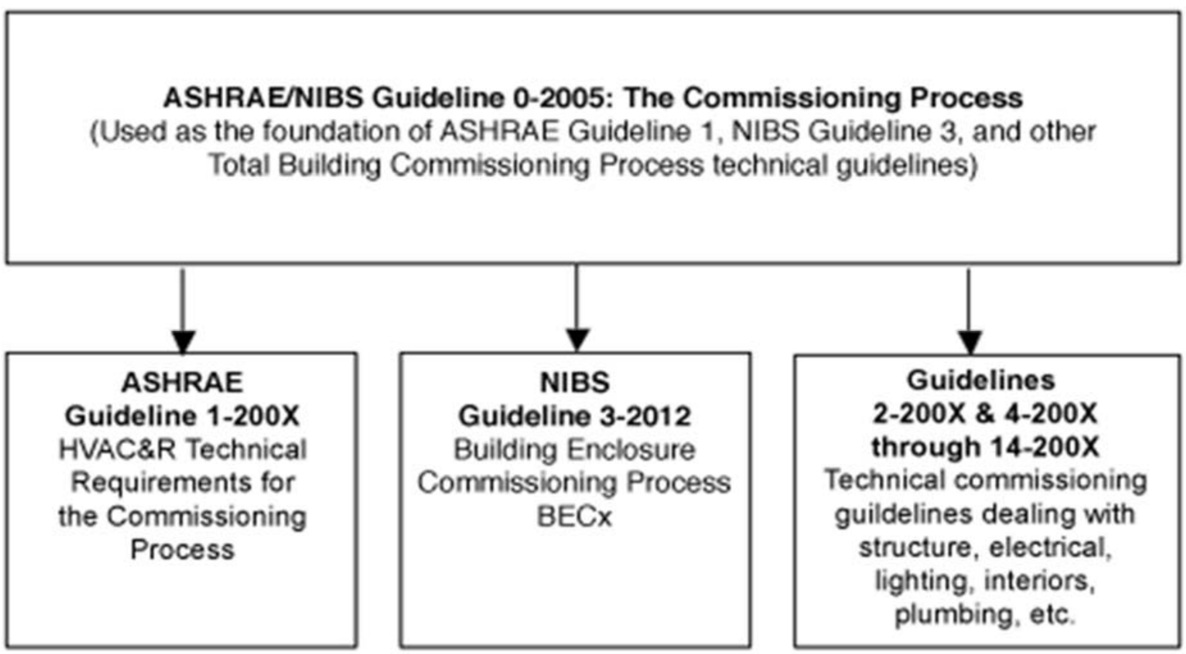
Meeting performance objectives is not achieved simply by a "Final Inspection" of the finished product, but is a sustained effort from inception and planning through turnover and operation to assure the delivery of a project that satisfies all of the owner's functional, psychological, and operational requirements for the project.

There are many aspects involved in assuring performance objectives are met, from assembling a qualified project delivery team; to adequately coordinating team member roles and responsibilities; to instituting systematic quality assurance programs, like Building Commissioning.

Meeting performance objectives is a sustained effort from inception and planning, through turnover and operation, to assure the delivery of a project that satisfies all of the owner's functional requirements for the building and psychological requisites for space users. Total Building Commissioning (TBCx) is one such quality assurance process that takes all the systems of the "Whole Building" into account to assure that the building performs as intended.

There are many aspects involved in assuring performance objectives are met; from assembling a qualified project delivery team; to adequately coordinating team member roles and responsibilities to instituting systematic quality assurance programs.

The National Institute of Building Sciences (NIBS) NIBS Total Building Commissioning Program is currently working with industry organizations to develop commissioning guidelines for various systems and assemblies.



NIBS Guideline 3-2012 Building Enclosure Commissioning Process BECx

The ability of a building to perform in a way that fully meets an owner's functional expectations and the psychological needs of its users—both qualitative and quantitative—requires a coordinated effort by a multi-disciplined team of experts who understand and apply a 'Whole Building' design approach.

Some practical ways to approach developing a proactive performance assurance program for a project include:

- Assure that appropriate programming occurs;
- Establish design objectives and priorities that will drive design concepts;
- Review "Lessons Learned" to leverage corporate knowledge and assure past mistakes are not repeated;
- Institute a project delivery quality assurance (QA) program;
- Understand the role of Facility Management and Operations; and
- Use Facility Performance Evaluations (FPE's).

RECOMMENDATIONS

Assure that Appropriate Programming Occurs

- Facilitate discussions with key stakeholders in establishing project requirements and goals.
- Facilitate a high level of communication between project team members during programming and throughout the facility development process.
- Identify mission critical programs and requirements.
- Clearly describe all functional needs and design intents.
- Communicate owners' special knowledge of what works well and what does not.
- Document all performance expectations.
- Address information technology (IT) and communication needs—both current and future.
- Incorporate infrastructure capability in the present that will accommodate and adapt for the programmatic needs of the future.

Establish Design Objectives and Priorities that will Drive Design Concepts

- Set performance goals for both building envelope and building systems.
- Look for unique aspects of the project to feature and enhance.
- Reconcile conflicting priorities (i.e. physical security vs. fire safety needs).
- Define qualitative and quantitative performance measures (e.g., sustainability, maintainability, functionality, etc.)

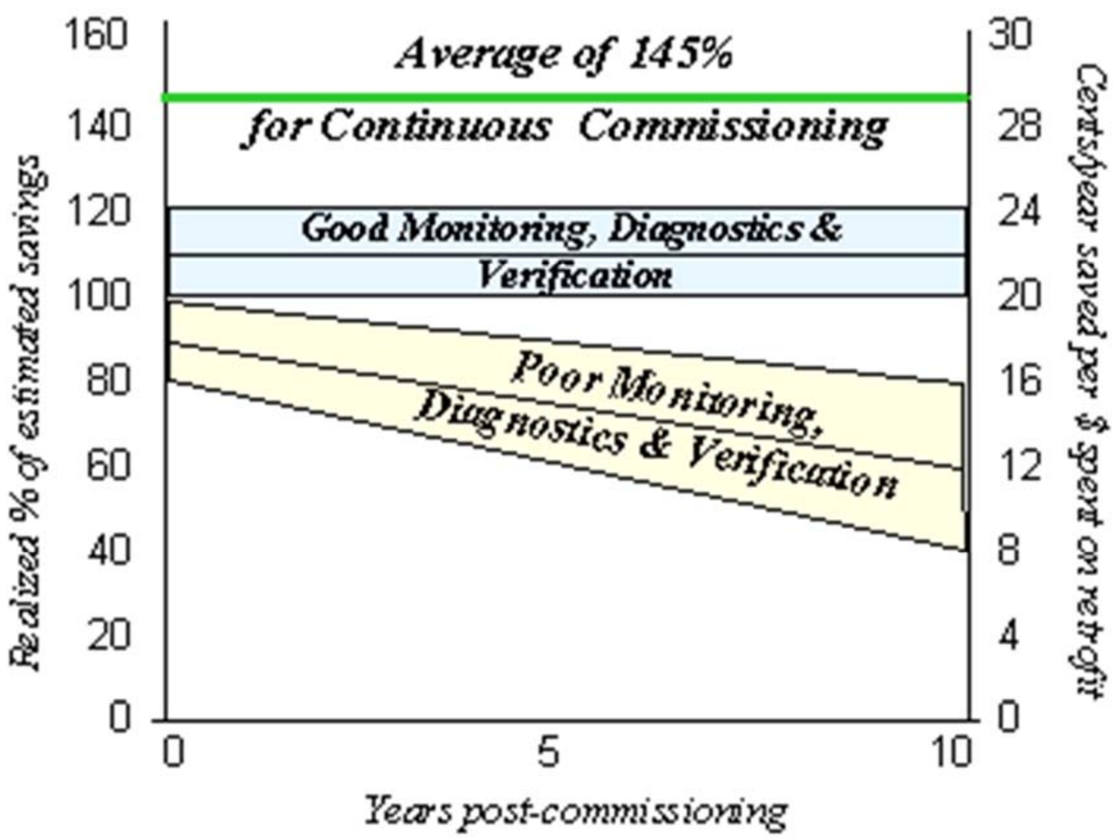
Institute a Project Delivery Quality Assurance (QA) Program

- Conduct thorough owner reviews of A-E designs and documentation.
- Track critical decisions to focus on design intents.
- Establish owner's measurable quality standards and metrics for performance expectations.
- Identify owner's tests and certification expectations.
- Hire an owner's representative, if necessary, to oversee performance assurance.
- Focus enhanced performance assurance measures on mission critical systems and features. Use the building process, as appropriate.
- Include training of facility operators on the interdependent function of systems integration.

This Environmental Management System (EMS) enables facilities engineering personnel to maintain comfort and ventilation levels at the high standards set by the stakeholders at the beginning of the project

Understand the Role of Facility Management and Operations

- Involve O&M staff in all design phases.
- Bring forward special knowledge and experiences of O&M staff into the design phases.
- Anticipate what it will take to maintain and operate the facility.
- Perform energy analysis in design phases; make sure operating budgets are addressed.
- Consider the unique aspects of operations and maintenance for historic structures.
- Include O&M stakeholders as partners in the performance optimization program.
- Document O&M procedures that contribute to optimal facility performance.



Savings from Continuous Commissioning Program in laboratory building at Texas A&M University

Use Facility Performance Evaluations (FPE's)

- Seek feedback from users and include it in performance optimization efforts through Post-Occupancy Evaluations. AIA has post occupancy evaluations. Go to www.aia.org and search 'post occupancy evaluation.'
- Use prototypes to evaluate the performance of designs to be repeated.
- Assure functional reliability through continued monitoring and analysis, and acting to correct degradation. OMSI (Operations & Maintenance Support Information) is NOT monitoring and analysis. It is the "Operating Manual" so to speak.

Relationship of Function / Operation and Cost

Care should always be used when undertaking cost management practices (i.e., Value Engineering, cost cutting, etc.) not to compromise the functional or operational performance of the interrelated and often interdependent systems.

Design Lessons Learned

Key to improving the facility planning, design, and delivery process is continual improvement of team performance through learning from and avoiding repeated design errors, omissions, or flaws in project execution. "Lessons Learned" is a common term that refers to an organization's compilation and publication of the lessons for the knowledge and benefit of future project teams.

Design of facilities that meet or exceed the functional expectations of owners and facility managers will require the application of these principles as well as thorough understanding of historical precedent and knowledge of current design practices for the building type.

Note: Information in these Functional pages must be considered together with other design objectives and within a total project context in order to achieve quality, high performance buildings.

Productivity

Wise use of space means creating the right context for concentration, learning, communication, and collaboration—the building blocks of productivity.

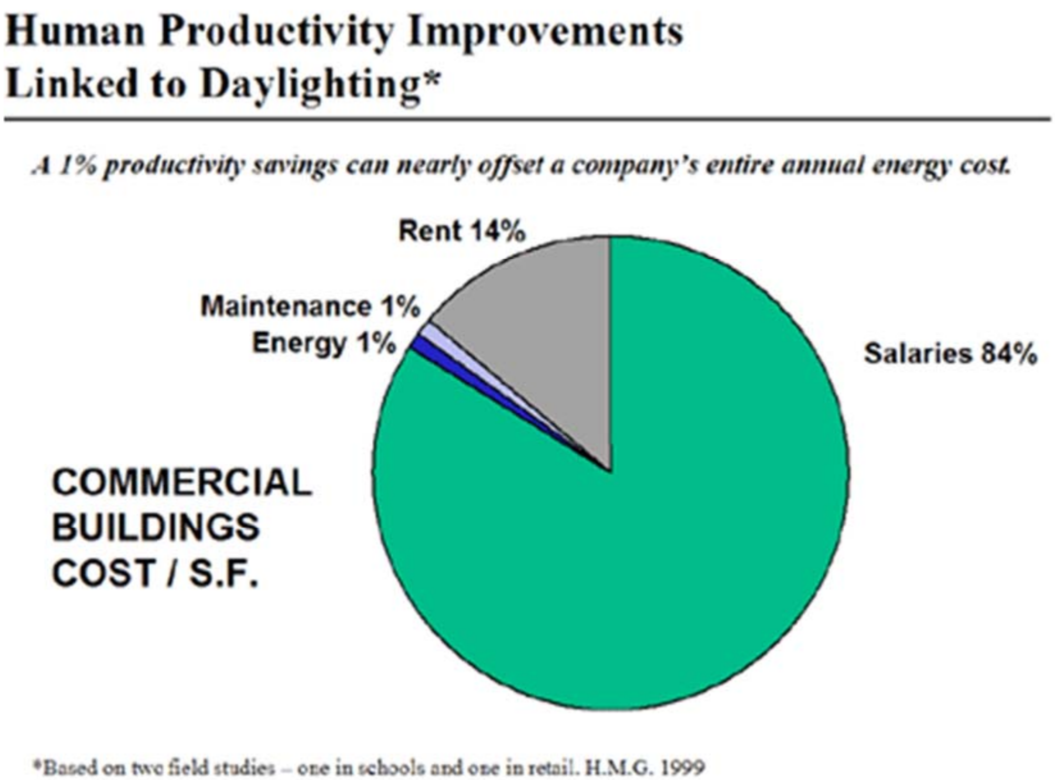
Organizations, business practices, educational settings and learning methodologies, and the workforce have changed dramatically in the past two decades. Technological advances, demographic shifts, and continual demands for innovation have created pressures for environments to catch up with the changing nature of organizations, work and workplace.

Organizational effectiveness today means using space more wisely. This does not just mean cutting costs. It means designing for flexibility to enable space to change as work groups, activities, and projects evolve. Information in these Productive pages must be considered together with other design objectives and within a total project context in order to achieve quality, high-performance buildings. Also, workplace productivity strategies support sustainable design principles and should be taken on balance for the longevity of all the issues considered.

The Office of Government-wide Policy at the GSA headquarters building in Washington, DC was designed to maximize flexibility, allowing new occupants to change the space to fit their group and individual needs.

It is often hard to quantify the impacts of specific components of the indoor environment on productivity, because individual and group effectiveness is tied to many different factors-including compensation levels, management practices, and environmental comfort.

It is difficult, if not impossible, to isolate individual physical factors, such as the presence or absence of team rooms, daylighting, natural meeting places, or control over the environment. This problem is exacerbated in the case of employees whose "output" is knowledge or insight that cannot be easily quantified.



Nonetheless, an increasing number of studies are beginning to suggest that support for communication and collaboration as well as for individual cognitive activity are fundamental aspects of organizational productivity. The GSA agrees and concludes in *The Integrated Workplace* that "since people are the most important resource and greatest expense of any organization, the long-term cost benefits of a properly designed, user-friendly work environment should be factored into any initial cost considerations."

One way to do such "factoring" is to consider the total life-cycle costs of the building or property each year. In private sector offices, such costs are typically, in order of magnitude:

- $200 per square foot per year for salaries
- $20 per square foot per year for amortized bricks and mortar costs, and
- $2.00 per square foot per year for energy.

In this situation, an additional $2 per square foot per year for bricks and mortar costs (e.g. for providing greater flexibility) would pay for itself if it generated a modest 1% increase in salary "productivity." Note: Design strategies that increase user satisfaction and that improve individual and group effectiveness should therefore be considered not as cost 'extras,' but as productivity investments that enhance an organization's overall success.

Buildings can be more effective, exciting places to work, learn, and live by encouraging adaptability, improving comfort, supporting sense of community, and by providing connections to the natural environment, natural light, and view.

Fundamental principles of productive building designs:

1. Promote Health and Well-Being

Indoor environments strongly affect human health. An effective environment should be designed to support and enhance the health and well-being of its occupants principles help achieve this objective.

2. Provide Comfortable Environments

An environment designed and operated to provide the highest achievable levels of visual, acoustic, and thermal comforts for its occupants is the underpinning of worker effectiveness.

3. Design for the Changing Workplace

Providing spaces with flexibility, social support, and technology to promote new ways of working, learning and engaging in a number of activities is a cornerstone of change and innovation.

4. Integrate Technological Tools

Effectively integrating technological tools and distribution networks required in today's environments to enable occupants to perform activities or their duties starts first and foremost with properly designed pathways and spaces.

5. Assure Reliable Systems and Spaces

Reliability is one of the greatest concerns for building occupants—it directly affects their safety, health, and comfort. Occupants must be able to rely on building systems, equipment, and tools that function consistently and are properly maintained.

Building Integrated Photovoltaics (BIPV)

INTRODUCTION

One of the most promising renewable energy technologies is photovoltaics. Photovoltaics (PV) is a truly elegant means of producing electricity on site, directly from the sun, without concern for energy supply or environmental harm. These solid-state devices simply make electricity out of sunlight, silently with no maintenance, no pollution, and no depletion of materials.

There is a growing consensus that distributed photovoltaic systems that provide electricity at the point of use will be the first to reach widespread commercialization. Chief among these distributed applications are PV power systems for individual buildings.

Interest in the building integration of photovoltaics, where the PV elements actually become an integral part of the building, often serving as the exterior weather skin, is growing worldwide. PV specialists and innovative designers in Europe, Japan, and the U.S. are now exploring creative ways of incorporating solar electricity into their work. A whole new vernacular of Solar Electric Architecture is beginning to emerge.

A Building Integrated Photovoltaics (BIPV) system consists of integrating photovoltaics modules into the building envelope, such as the roof or the façade. By simultaneously serving as building envelope material and power generator, BIPV systems can provide savings in materials and electricity costs, reduce use of fossil fuels and emission of ozone depleting gases, and add architectural interest to the building.

While the majority of BIPV systems are interfaced with the available utility grid, BIPV may also be used in stand-alone, off-grid systems. One of the benefits of grid-tied BIPV systems is that, with a cooperative utility policy, the storage system is essentially free. It is also 100% efficient and unlimited in capacity. Both the building owner and the utility benefit with grid-tied BIPV. The on-site production of solar electricity is typically greatest at or near the time of a building's and the utility's peak loads. The solar contribution reduces energy costs for the building owner while the exported solar electricity helps support the utility grid during the time of its greatest demand.

DESCRIPTION

Photovoltaics (PV) Technologies

There are two basic commercial PV module technologies available on the market today:

1. ***Thick crystal products*** include solar cells made from crystalline silicon either as single or poly-crystalline wafers and deliver about 10-12 watts per ft² of PV array (under full sun).
2. ***Thin-film products*** typically incorporate very thin layers of photovoltaicly active material placed on a glass superstrate or a metal substrate using vacuum-deposition manufacturing techniques similar to those employed in the coating of architectural glass. Presently, commercial thin-film materials deliver about 4-5 watts per ft² of PV array area (under full sun). Thin-film technologies hold out the promise of lower costs due to much lower requirements for active materials and energy in their production when compared to thick-crystal products.

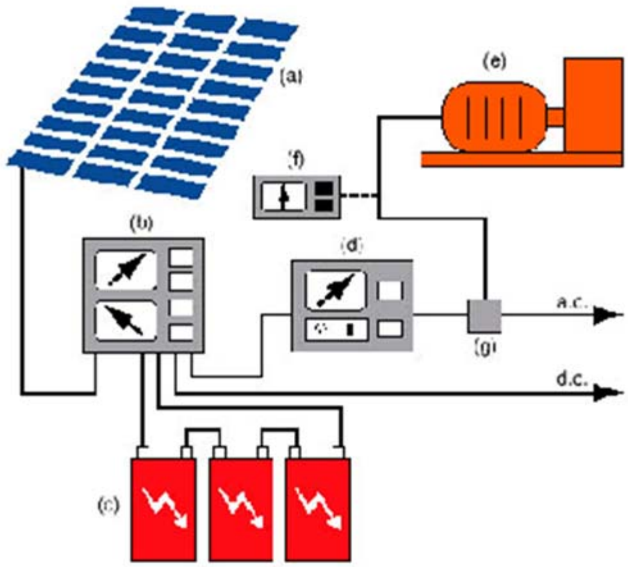
A photovoltaic system is constructed by assembling a number of individual collectors called modules electrically and mechanically into an array.

Building Integrated Photovoltaics (BIPV) System

Building Integrated Photovoltaics (BIPV) is the integration of photovoltaics (PV) into the building envelope. The PV modules serve the dual function of building skin—replacing conventional building envelope materials—and power generator. By avoiding the cost of conventional materials, the incremental cost of photovoltaics is reduced and its life-cycle cost is improved. That is, BIPV systems often have lower overall costs than PV systems requiring separate, dedicated, mounting systems.

A complete BIPV system includes:

- the PV modules (which might be thin-film or crystalline, transparent, semi-transparent, or opaque);
- a charge controller, to regulate the power into and out of the battery storage bank (in stand-alone systems);
- a power storage system, generally comprised of the utility grid in utility-interactive systems or, a number of batteries in stand-alone systems;
- power conversion equipment including an inverter to convert the PV modules' DC output to AC compatible with the utility grid;
- backup power supplies such as diesel generators (optional-typically employed in stand-alone systems); and
- appropriate support and mounting hardware, wiring, and safety disconnects.



BIPV system diagram

BIPV systems can either be interfaced with the available utility grid or they may be designed as stand-alone, off-grid systems. The benefits of power production at the point of use include savings to the utility in the losses associated with transmission and distribution (known as 'grid support'), and savings to the consumer through lower electric bills because of peak shaving (matching peak production with periods of peak demand). Moreover, buildings that produce power using renewable energy sources reduce the demands on traditional utility generators, often reducing the overall emissions of climate-change gasses.

Design of a Building Integrated Photovoltaics (BIPV) System

BIPV systems should be approached to where energy conscious design techniques have been employed, and equipment and systems have been carefully selected and specified. They should be viewed in terms of life-cycle cost, and not just initial, first-cost because the overall cost may be reduced by the avoided costs of the building materials and labor they replace. Design considerations for BIPV systems must include the building's use and electrical loads, its location and orientation, the appropriate building and safety codes, and the relevant utility issues and costs.

Steps in designing a BIPV system include:

1. ***Carefully consider the application of energy-conscious design practices and/or energy-efficiency measures to reduce the energy requirements of the***

building. This will enhance comfort and save money while also enabling a given BIPV system to provide a greater percentage contribution to the load.

2. ***Choose Between a Utility-Interactive PV System and a Stand-alone PV System:***

   The vast majority of BIPV systems will be tied to a utility grid, using the grid as storage and backup. The systems should be sized to meet the goals of the owner—typically defined by budget or space constraints; and, the inverter must be chosen with an understanding of the requirements of the utility.

   For those 'stand-alone' systems powered by PV alone, the system, including storage, must be sized to meet the peak demand/lowest power production projections of the building. To avoid over sizing the PV/battery system for unusual or occasional peak loads, a backup generator is often used. This kind of system is sometimes referred to as a "PV-genset hybrid."

3. ***Shift the Peak:*** If the peak building loads do not match the peak power output of the PV array, it may be economically appropriate to incorporate batteries into certain grid-tied systems to offset the most expensive power demand periods. This system could also act as an uninterruptible power system (UPS).

4. ***Provide Adequate Ventilation:*** PV conversion efficiencies are reduced by elevated operating temperatures. This is truer with crystalline silicon PV cells than amorphous silicon thin-films. To improve conversion efficiency, allow appropriate ventilation behind the modules to dissipate heat.

5. ***Evaluate Using Hybrid PV-Solar Thermal Systems:*** As an option to optimize system efficiency, a designer may choose to capture and utilize the solar thermal resource developed through the heating of the modules. This can be attractive in cold climates for the pre-heating of incoming ventilation make-up air.

6. ***Consider Integrating Daylighting and Photovoltaic Collection:*** Using semi-transparent thin-film modules, or crystalline modules with custom-spaced cells between two layers of glass, designers may use PV to create unique daylighting features in façade, roofing, or skylight PV systems. The BIPV elements can also help to reduce unwanted cooling load and glare associated with large expanses of architectural glazing.

7. ***Incorporate PV Modules into Shading Devices:*** PV arrays conceived as "eyebrows" or awnings over view glass areas of a building can provide appropriate passive solar shading. When sunshades are considered as part of an integrated design approach, chiller capacity can often be smaller and perimeter cooling distribution reduced or even eliminated.

8. ***Design for the Local Climate and Environment:*** Designers should understand the impacts of the climate and environment on the array output. Cold, clear days will increase power production, while hot, overcast days will reduce array output;

- Surfaces reflecting light onto the array (e.g., snow) will increase the array output;
- Arrays must be designed for potential snow- and wind-loading conditions;
- Properly angled arrays will shed snow loads relatively quickly; and,
- Arrays in dry, dusty environments or environments with heavy industrial or traffic (auto, airline) pollution will require washing to limit efficiency losses.

9. ***Address Site Planning and Orientation Issues:*** Early in the design phase, ensure that your solar array will receive maximum exposure to the sun and will not be shaded by site obstructions such as nearby buildings or trees. It is particularly important that the system be completely unshaded during the peak solar collection period consisting of three hours on either side of solar noon. The impact of shading on a PV array has a much greater influence on the electrical harvest than the footprint of the shadow.

10. ***Consider Array Orientation:*** Different array orientation can have a significant impact on the annual energy output of a system, with tilted arrays generating 50%-70% more electricity than a vertical façade.

11. ***Reduce Building Envelope and Other On-site Loads:*** Minimize the loads experienced by the BIPV system. Employ daylighting, energy-efficient motors, and other peak reduction strategies whenever possible.

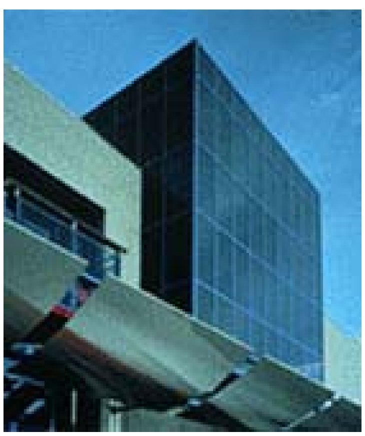
12. ***Professionals:*** The use of BIPV is relatively new. Ensure that the design, installation, and maintenance professionals involved with the project are properly trained, licensed, certified, and experienced in PV systems work.

In addition, BIPV systems can be designed to blend with traditional building materials and designs, or they may be used to create a high-technology, future-oriented appearance. Semi-transparent arrays of spaced crystalline cells can provide diffuse, interior natural lighting. High profile systems can also signal a desire on the part of the owner to provide an environmentally conscious work environment.

APPLICATION OF PHOTOVOLTAICS

Photovoltaics may be integrated into many different assemblies within a building envelope:

- Solar cells can be incorporated into the façade of a building, complementing or replacing traditional view or spandrel glass. Often, these installations are vertical, reducing access to available solar resources, but the large surface area of buildings can help compensate for the reduced power.
- Photovoltaics may be incorporated into awnings and saw-tooth designs on a building façade. These increase access to direct sunlight while providing additional architectural benefits such as passive shading.
- The use of PV in roofing systems can provide a direct replacement for batten and seam metal roofing and traditional 3-tab asphalt shingles.
- Using PV for skylight systems can be both an economical use of PV and an exciting design feature.



Left to right: APS Factory in Fairfield, CA and Intercultural Center, Georgetown University in Washington, DC

Project Planning, Delivery and Controls

OVERVIEW

Excellence in Project Management is achieved through a structured process that includes multiple phases:

- Initiating
- Planning
- Executing
- Monitoring and Controlling
- Closing.

The process balances the key project constraints and provides a tool for making decisions throughout the project based on stakeholder values, performance metrics, established procedures and project goals.

Effective project management includes strategies, tactics, and tools for managing the design and construction delivery processes and for controlling key factors to ensure the client receives a facility that matches their expectations and functions as it is intended to function. Improvements in building quality directly contribute to reduced operational costs and increased satisfaction for all of the stakeholders.

Successful project delivery requires the implementation of management systems that will control changes in the key factors of scope, costs, schedule, and quality to maximize the investment. This section offers guidance for the entire team to successfully and effectively carry out a high performance building project.

It is critical to establish the qualities of the project that are necessary to satisfy client and end user needs and expectations, once it is delivered and in use. Value for the money in construction requires completing a project on time, on budget and to a level of quality that meets the determined needs.

A well-programmed project will continue to provide value and meet user needs throughout its lifetime and will contribute positively to the environment in which it is located with a wide range of social and economic benefits. Early investment in planning, programming, and design can help deliver these benefits and avoid unnecessary costs and delays.

Contemporary institutions and organizations are increasingly realizing that traditional forms of management—based on the same approach to every project—cannot meet the needs of today's economic, social, and business environment. Additionally, the processes can be streamlined based on technologies and efficiencies not previously available.

The responsibility for delivering a project as planned rests with the entire team. When evaluating options, the whole-life value should be considered and not limited to the short term initial investment. Factors that affect the longer term costs of a facility, such as maintainability, useful service life, and resource consumption should be integrated into the decision matrix.

Project Delivery Teams

OVERVIEW

Every capital project has a unique set of program goals and technical requirements that demand assembling a specialized mix of core team members and other stakeholders (a stakeholder is a party with a vested interest in a project). Successful project management involves continuous leadership of the team through successful project planning and development and through project delivery and control.

It also involves establishing quality control processes for each team member to better understand those goals and objectives determined by the owners of the project. Early involvement of all parties through an integrated delivery process ensures that the expertise of the professionals involved at all stages will work to improve process and delivery stages for the project.

Assembling a Project Delivery Team

Delivery teams typically include those professionals involved in the programming, planning, design, construction and sub-contractor roles for the project. Assembling the correct team is critical to achieving the best outcomes possible and minimizing risk and loss.

The extent of professional disciplines and technical specialists (often called Program Advocates) represented on the delivery team will vary depending on the extent of the managing agency's capital design and construction budget and their associated management, professional and support staff resources. Delivery team members should be identified in the Project Management Plan (PMP) and typically will include a project manager, contracting officer, owner/client representative, A-E professionals, commissioning agent, facility manager, representatives of the O&M staff, specialty consultants, construction contractor, construction manager, and peer reviewer(s).

Partnering

Partnering, often referred to as dispute prevention, is a formal program used by the Project Delivery Team to improve communications and avoid disputes by working towards mutually beneficial goals and project objectives. Partnering creates opportunities for higher performing projects, more efficient resolution of issues, higher levels of trust and personal satisfaction, and increased collaboration.

The partnering process typically starts during preconstruction where an initial workshop or session is held. During the workshop, members of the Project Delivery Team meet to define their goals for the project, identify lines of communication, and establish a conflict resolution process.

At the conclusion of the workshop, members of the Project Delivery Team will sign a formal partnering agreement, or charter, that will serve as a non-binding document to remind team members of their commitment to the process and goals. Follow-up partnering sessions are held throughout the life cycle of the project to address project issues and concerns, review performance according to the partnering charter, and refine processes.

Project Delivery Teams may benefit from a third-party facilitator, or consultant, with knowledge of partnering to facilitate and continuously improve their program.

Integrated Project Delivery

Integrated Project Delivery (IPD) is an approach to the design and construction process that is based on a cooperative working relationship, shared risk and reward, and open exchange of information that is intended to optimize project results, increase value to the Owner, and reduce waste during all phases of the project. IPD unifies the Project Delivery Team at the beginning of the project with the shared goal of project success.

The principles of IPD can be applied to a project in two ways—IPD as a Philosophy and IPD as a Delivery Method. IPD as a Philosophy occurs when integrated practices or philosophies are applied to more traditional project delivery methods such as Design/Bid/Build, Design/Build, and CM at-Risk. The degree of collaboration may vary with IPD as Philosophy, but most or all elements are not contractually binding. IPD as a Delivery Method occurs when an Owner signs a multi-party contract with key members of the Project Delivery Team that incentivizes collaboration, team risk-sharing, and other IPD principles and practices.

Contracting and Acquisition

Project Managers work closely with agency contracting officers in assembling the project delivery team. They need to have familiarity with acquisition and contracting regulations and procedures applicable to the managing agency, but only contracting officers (often referred to as the "CO") are permitted to contract for professional and construction services on behalf of the government.

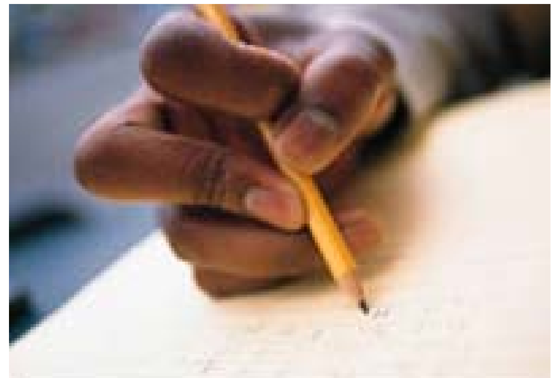
Acquisition Regulations specify procedures for advertising work, selection stages of submissions, and contractor evaluation and selection criteria. The *"Brooks Bill"* is a procurement method that allows awarding projects to the best qualified, rather than lowest priced, offer. Advertisement, evaluation, and selection are followed by contract negotiation and award of the assignment. Many agencies have developed and adopted standard forms for professional services and construction contracts.

Budget cycle considerations will also impact the project planning process. Depending on the scale of a project, funds for site purchase, design fees, and construction costs may be spread over several budget cycles. Contracting for each phase of work may only occur after funds are requested in agency budgets and have been appropriated or authorized.

In the private sector references, past experience and certification determine who the various professional team members will be. It is important to look for experience in similar types of projects and for the credentials and recent experience of the people involved.

Early contractor and designer involvement enhances this process so that all stakeholders are involved in setting the specifications for the project to more forward efficiently. It is also important to consider experience with sustainability issues to enhance project performance and the relationships with the community.

Defining Roles/Responsibilities and Team Management



Project Managers develop and define roles and responsibilities for each team member through the use of Project Management Plans, agency handbooks/guidelines, Commissioning Plans, RFPs, Scopes of Work, and Contracts.

Because project requirements and solutions evolve during the design phase (and even into the construction phase) a high degree of ongoing coordination among team members is needed for an integrated effort that will result in projects that are on time, in budget, function properly, and meet the project owner's expectations. A good quality control process provides needed documentation of the project goals and objectives and helps keep these goals at the forefront of the planning process.

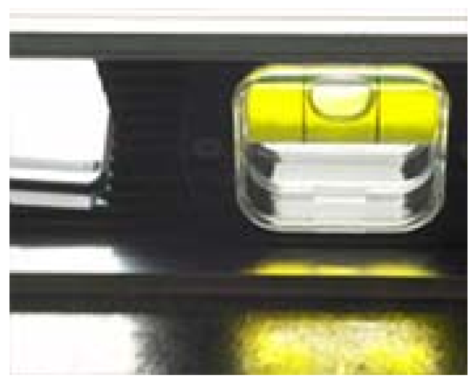
Project Management Practices and Standards

Successful project management of a major, complex design and construction program requires mastery of a body of knowledge (BOK) including proficiency in project planning, development, design, scheduling, cost management, codes and regulations, contract law, and exceptional communication and interpersonal skills. These professional skills are necessary for effective and successful project leadership and improve the performance of the team as a whole.

Project Requirements

Project inception and preliminary planning require thoughtful definition of goals and needs (Project Scope); master planning to accommodate anticipated future needs; evaluation of project alternatives; identification of site requirements; funding requirements; budget authorization cycles and/or financial impacts; and project phasing. There are tools available that help define the goals and objectives for the project that let all stakeholders have a voice in making the project successful. The risks associated with making mistakes in this part of the process are great, since their impact will be felt across the project development process and in the final project results. For more information, see links below in the Major Resources section.

Scope Management



Project scope is the work that must be performed to meet a client's program goals for space, function, features, impact, and level of quality. Scope management sets the boundaries for the project and is the foundation on which the other project elements are built. From the beginning it helps identify the work tasks and their requirements for completion. Effective scope management requires accurate definition of a client's requirements in the Planning and Development stage and a systematic process for monitoring and managing all the factors that may impact or change the program requirements throughout the project design and construction phases through delivery of the finished project.

Cost Management

Project costs are measured and analyzed in many ways throughout a project, from planning, programming and design to bidding, construction, turnover, and post occupancy. First costs, cost-benefit ratios, and life-cycle costing are a few examples of how a project's cost-effectiveness can be evaluated. The control of costs requires continual and systematic cost management and monitoring to compare actual costs incurred against targeted budget numbers. These cost management processes start with the establishment of budgets based on actual estimates for related work. They need to align with scope and quality requirements and be based on realistic, current market conditions. Comparing budgets to actual costs throughout the building process is critical. The process continues with milestone estimates, value engineering, procurement strategies, and change order management to ensure the project is timely and cost-effective.

Schedule Management

A project schedule defines the processes and establishes a timeline for delivering the project. Avoiding missing deadlines for delivery of key project components is a key objective of schedule management. Comprehensive project schedules will identify all of the project's stages, phases, and activities assigned to each team member mapping them to a timeline that measures key dates that are used to keep track of work progress. Schedule management interfaces directly with scope, cost, and quality management and team member roles and activities must be defined, coordinated, and continually monitored. It is the goal of every project manager to look for efficiencies in all of these areas as a project progresses.

Delivery Methods

There are many approaches to achieve successful project design and construction. The Delivery Methods are driven by the project's scope, budget, and schedule. Some of these methods include Traditional (Design/Bid/Build), Integrated Delivery Process (where all stakeholders have a financial incentive to work together to produce the desired results), CM (also called CMc, or Construction Manager), Design-Build, Bridging, Lease/Build and Lease Buy Back. The selection of a delivery method will in turn influence the team composition, schedule, budget, and management plans to be followed throughout the process.

Project Management Plans

A Project Management Plan (PMP) documents key management and oversight tasks and is updated throughout the project as changes occur. The plan includes definition of an owner's program goals, technical requirements, schedules, resources, budgets, and management programs. It also provides a vehicle for including efficiencies in the design and construction phases of all buildings. It will also serve as the basis for completed construction documents and outline the commissioning plan for finished execution.

Risk Management

INTRODUCTION

In design and construction, risk analysis can be described as a systematic methodology and ongoing process by which occurrences that may substantially affect the end product (i.e. risks) can be identified, quantified, modeled, managed, and monitored. This tool is especially useful as a method of good project management and planning, because the business of building is inherently risky—the risk mitigation methods can be applied to project cost, schedule, quality/performance, safety, and business operations.

Good risk management procedures ultimately measure the team's confidence level in the project on an ongoing basis, and allow the introduction of corrective actions, monetary contingency, and schedule float in order to minimize losses to the project and increase the likelihood of the project being completed on schedule and within budget.

The application of risk management procedures in construction can give early visibility to potential "problem areas" and opportunities, where effort and money can be expended early in the design and construction phases to reduce vulnerability, insurance costs, business or mission interruption, and claims.

Early risk identification ensures that design and team effort is concentrated in critical areas, focusing the project team's attention on actions and resources where there is a major risk exposure, or where the greatest time/cost savings can be made through reengineering and streamlined project management.

The objective is proactive management of projects, where problems are reduced as they are identified, as differentiated from the traditional approach to construction, which waits until critical problems develop and then implements an immediate (and typically expensive) response which may reduce the impact to the project but likely does not avoid losses as effectively as early risk response. Over time, risk management allows the project team to build a historical profile of risk based upon experience and lessons learned, which will allow for better management of future projects.

Risk management is an organized method of identifying and measuring risk and then developing, selecting, implementing and managing options for addressing risks. There are several types of risk that an owner should consider as part of risk management methodology. These include:

- Schedule risk
- Cost risk
- Technical feasibility
- Risk of technical obsolescence

- Dependencies between a new project and other projects
- Physical events beyond direct control

Risk management seeks to identify and ultimately control possible future events and should be proactive rather than reactive. To be effective, risk management must rely on tools and techniques that help predict the likelihood of future events, the effects of these future events and methods to deal with these future events. Risk management should really be considered the responsibility of everyone involved in a project.

Risk Tools and Techniques

Paying attention to detail and implementing appropriate cost and schedule control systems will assist in risk analysis and management. Best practice guidelines in this area include the *Management of Risk* by the Institute of Risk Management, the *Practice Standard for Project Risk Management* by the Project Management Institute, and *Risk Analysis and Management for Projects* by the Institute of Actuaries and Civil Engineers.

A key element is to develop levels of confidence around various financial outcomes, sometimes known as Confidence Modeling. This assists in the calculation of appropriate levels of contingency to be included at each stage of the project life cycle.

A technique to accomplish this is the use of range estimating as a risk analysis tool. Range estimating can be done in a rather simple fashion by selecting the 20 percent of the line items in an estimate that represent 80 percent of the cost then developing a range for each of those 20 percent and doing a simple process of adding the low and high ranges.

A more advanced approach could take the same 20 percent items, establish the range and then use any one of several available software packages to perform a Monte Carlo simulation (which is a problem solving technique used to approximate the probability of certain outcomes by running multiple trial runs, called simulations, using random variables) and produce a risk profile.

This approach would give a more accurate projection of the logical highs and lows involved with 20 percent drivers. A sensitivity analysis can also be prepared to vary the key risk parameters.

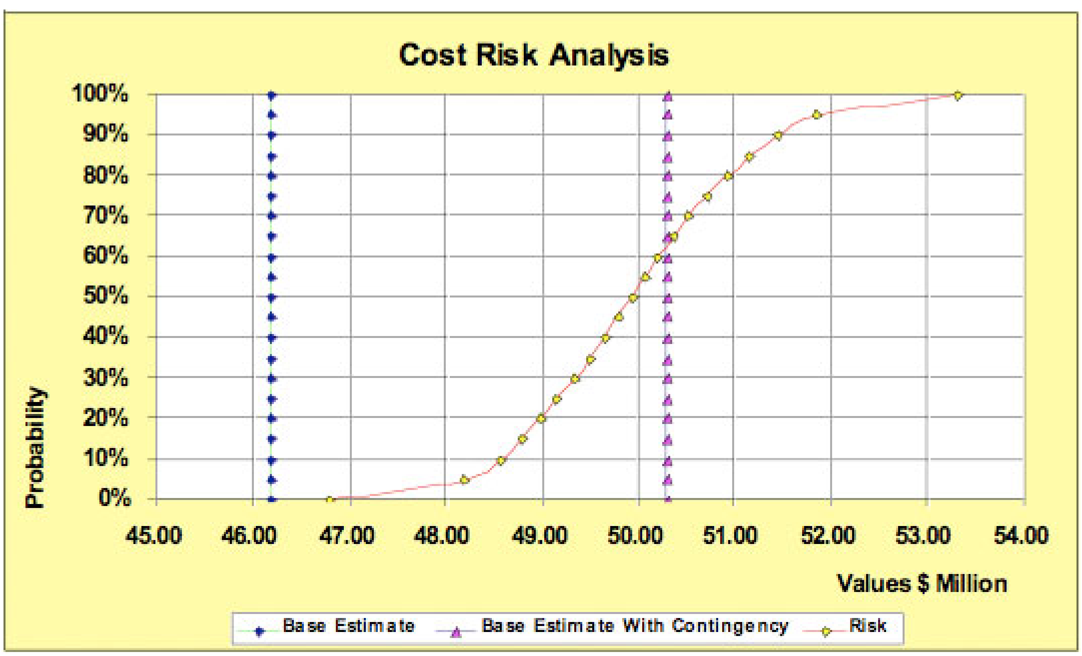
Finally, it is possible to use a complete risk analysis package that includes range estimating and prepares a risk profile that estimates confidence ranges and contingency amounts. This type of an approach can establish contingencies for not only individual projects but for entire programs.

Monte Carlo or risk analysis is used when establishing a baseline or baseline change during budget formulation. The contingency developed from the Monte Carlo analyses should fall within the contingency allowance ranges presented previously.

Monte Carlo analyses and other risk assessment techniques use similar methodology to obtain contingency estimates. There are a number of software packages both publicly and commercially available. The estimator must subdivide the estimate into separate phases or tasks and assess the accuracy of the cost estimate data in each phase.

After the project data have been input and checked, the software will calculate various contingencies for the overall project based on the probability of project underrun. The random number generator accounts for the known estimate accuracy. Once the program has completed its iterations (usually 1,000), it produces an overall contingency for the project with certain accuracy.

The application of this type of quantitative risk analysis allows the construction project exposure to be modeled, and quantifies the probability of occurrence and potential impact of identified risks. The results can be used to produce a realistic representation, in graphic s-curve form, of the project's total uncertainty and risks. Referring to the s-curve figure below as an example, a contingency amount of approximately $3.54 million on top of the base estimate amount of $46.7m represents 65% confidence in achieving that project cost. For 80% confidence, contingency should be increased such that total project cost is $51 million.



Sample project cost s-curve

Risk management with probabilistic modeling can be used to reduce project contingency from a guesstimate of 10-20% to a quantitatively determined amount, typically in the range of 3-8%. Consistent with broader quality management principles, the team can make data-driven decisions specifically for that project, as opposed to relying on past rules-of-thumb. As the project progresses, and the confidence level in project cost increases, the early release of contingency amounts may be achieved and the money may be invested elsewhere.

Risk Mitigation and Monitoring

Risk mitigation and the development of appropriate response actions is often the weakest part of the risk management process - the ongoing management and monitoring of identified risks, and the addition of new risks to the model, require constant vigilance.

When managing risks, there are several risk strategy options to be considered. Risks may be avoided entirely (usually by eliminating their cause or root), transferred to another party (through contracts or insurance), or exposure to the risk can be reduced (through planned action measures). Acceptance of the risk should be considered only as a last resort, and should only be applied for items that cannot be addressed by any other strategy.

For each risk item, an achievable target risk reduction goal should be set, and proactive steps or action items identified by which the goal can be attained. The mitigation steps must be appropriate, cost effective, and achievable. The development of these steps should encourage problem solving and innovative solutions, with the objective of avoiding the risks or reducing their impact as much as possible.

When discussing action items, it is important to remember that interpretation of each risk will differ from person to person, with the recommended course of action varying according to the person or organization's perceptions of project management, objectives, environment, experience, and risk tolerance level. Similarly, opportunities can be discussed, and steps or action items developed which can increase their probability of occurrence or their level of impact.

In addition to creating action items for the risk, the risk manager may want to ask the following questions:

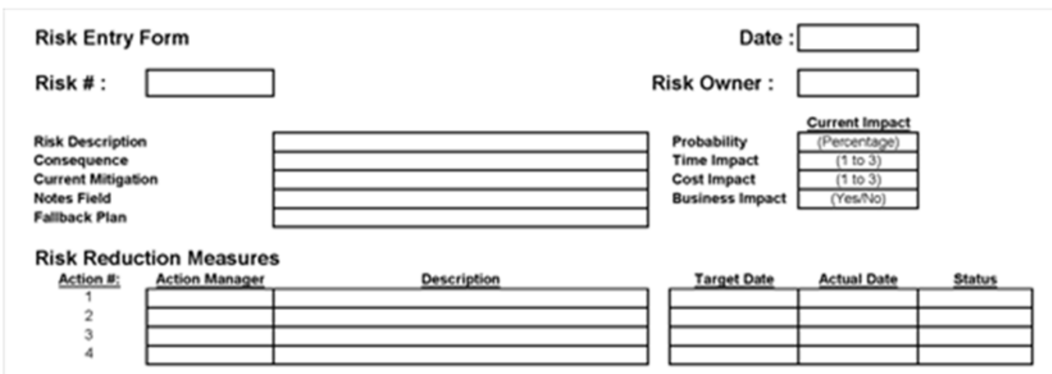
- What is the root cause or trigger for this risk?
- Does this risk have an impact on business, or just on the project?
- How will we know when the risk has occurred?
- What will happen if the risk occurs?
- How are we currently handling this risk?
- What steps can we take to better manage or mitigate this risk?

- What should we do if we fail to manage this risk?

The risk assessment sheet (RAS), or Risk Entry Form, is the appropriate place to record all known information about the risk. The RAS can also be managed in a database environment, such as MS Access.

Sample risk assessment sheet with action items

Risk management is an ongoing and iterative process, which should be conducted throughout the lifecycle of the project. Each risk manager must review all of their risks on a monthly basis or more frequently, and update the risk assessment sheets, even if only to note that there has been no change.



Risk Entry Form Date :

Risk # : Risk Owner :

Risk Description
Consequence
Current Mitigation
Notes Field
Fallback Plan

	Current Impact
Probability	(Percentage)
Time Impact	(1 to 3)
Cost Impact	(1 to 3)
Business Impact	(Yes/No)

Risk Reduction Measures

Action #:	Action Manager	Description	Target Date	Actual Date	Status
1					
2					
3					
4					

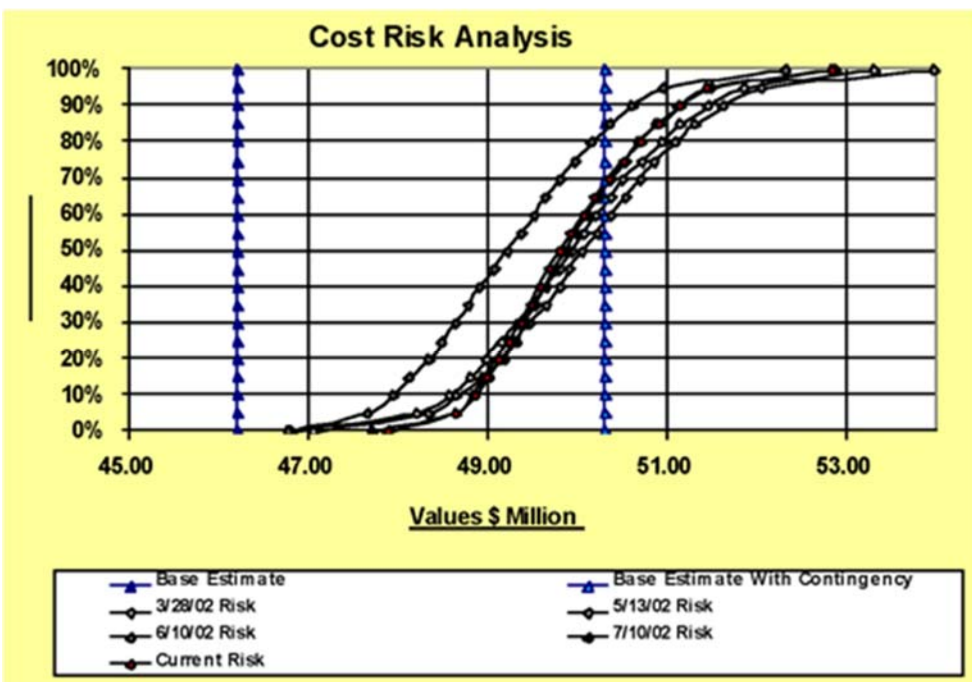
The risk management cycle

The risk management process or program is typically driven by a single individual, the project risk manager, in concert with the project manager or other high-level oversight. Individual accountability for risks can be assigned, such that each risk has its own manager. Updates from the risk managers are collated on a periodic basis by the project risk manager, and added to the model.

Risk status communication and awareness must occur regularly as a normal part of project meetings, so as to note changes to existing risks. The risk probability of occurrence may increase or decrease, as may the time and cost impacts. Changes to the estimate line items, such as updated equipment quotes or actual costs, must also be updated in the model.

As action items are implemented and the original risks are reduced, additional "secondary risks" may arise, which need to be added to the model. As design and construction progress, new risks will also be identified. Changes in scope can also be accommodated in the risk model, through analysis of their overall effect on the outcome of the project. The steps of identify-quantify-model-manage need to be taken for all new risks, secondary risks, and changes in project scope.

The nature of construction is such that, as time passes, the range of minimum and maximum expected values narrows, and confidence level in the most likely value increases, for each modeled risk item. This causes the project s-curve to straighten out, and its location to move to the right or left as exposure to risk either increases or decreases. The project risk manager must thus regularly review and update the risk model, and re-run the risk simulation.



Sample project cost s-curve after several iterations

As the project risk is being monitored, the data and trends can be collected and compared against the baseline risk assessment. From these trends, progress can be measured and "lessons learned" can be documented. The information can also be stored as historic risk data for future projects.

Conclusion

Risk management is a proactive project management tool used to reduce the susceptibility to losses incurred during a course of action, which leaves an auditable trail of changes. The process focuses project resources on reducing vulnerability, providing early visibility of potential problem areas and creating mitigation actions.

Good risk management should involve the entire project team, including design, engineering, business, contracts, finance, purchasing, estimating, and project controls. The process is ongoing, a never-ending cycle and iterative process of identification, quantification, modeling, management and monitoring. The analysis can include identified risks, estimate and schedule items, new risks, secondary risks, scope changes, change orders, and actual costs, so as to provide a graphic depiction of the changing nature of project risk over time.

As mentioned above, risk management with probabilistic modeling can be used to reduce project contingency from a guesstimate of 10-20% to a quantitatively determined amount, typically in the range of 3-8%. As the project progresses, and the confidence level in project cost increases, the early release of contingency amounts may be achieved and the money may be invested elsewhere.

Determine Project Performance Requirements

Every project goes through Pre-Design and Design Stages that establish an owner's needs, goals, scope, and design solutions for a proposed project. Proposed designs and constructed work can only be evaluated against objective criteria and measures that are embodied in well-documented project requirements. Project development is a learning process where building performance decisions are refined to successive levels of detail over the course a of project's life cycle. Key commissioning activities supporting this principle include:

- Understand Needs of Special Building Types
- Define Threats, Risks, and Consequences
- Determine Key Program Goals and Objectives
- Recognize Systems Criticality to Achieving Goals
- Conduct Key Commissioning Programming Activities

Determine Key Program Goals and Objectives

Commissioning of mission critical facilities is often focused on ensuring high levels of reliability, power quality, maintainability, and flexibility—as well as other design objectives and building system attributes. Programming for commissioning requires going beyond the simple allocation of space, enclosure, finish, and equipment to examine business goals and facility mission as determinants of its programming goals and objectives. Design objectives and functional characteristics that need commissioning to verify building performance may include:

- Accessibility
- 24x7 facility reliability
- Adaptability
- Building pressurization control
- Energy and water efficiency
- Flexibility in audio visual systems
- Functionality
- Maintainability
- Redundant and resilient HVAC systems for climate control
- Reliability

- Scalability
- Security / Safety
- Serviceability
- Sophisticated detection and fire suppression systems
- Space and organizational process functionality
- Structured raceways for flexible cabling installations
- Sustainability
- Survivability

Define Threats, Risks, and Consequences

In order to determine performance expectations and measures, the project team must have a clear understanding of overall key business objectives. The project owner must guide the project team in establishing and documenting (in the OPR as well as elsewhere) priorities by which project success will be measured. It is important for the owner or qualified experts to define business risks, occupant threats and risks, hazards, consequences, and impacts that a system failure may have on the overall mission performance of a facility, so that the CxP considers these defined priorities when reviewing and verifying integrated systems performance.

Recognize Systems' Criticality to Achieving Goals

System criticality, and the need for its performance verification through commissioning, is determined by examining how each system, assembly, or building feature, and the integrated aggregate systems, support key program goals and facility mission. For example, buildings with a high risk of airborne contamination must be designed for enhanced occupant safety measures. This may necessitate high-performance HVAC system design that provides constant airflow direction and pressure differentials between interior spaces under all operating conditions. This type of building functionality can only be achieved through both systems and whole building-based planning, design, construction quality assurance, and commissioning testing and verification of the operating systems under various conditions.

Systems		Aesthetics	Productivity	Sustainability	Security	Seismic	Fire Safety	Accessibility	Historic Pres.	Oper. & Main.
		Program Goals								
Foundations		1	1	1	1	3	1	1	1	1
Basement Construction		1	1	2	2	3	1	1	1	1
Superstructure		2	1	2	3	3	2	2	2	1
Exterior Walls		3	2	3	3	3	2	1	3	2
Exterior Glazing/Doors	Windows	3	3	3	3	2	2	1	2	3
	Doors	2	2	2	3	2	2	3	2	2
	Special, Atria	3	2	2	3	2	3	1	2	3
Roofing	Coverings	2	1	3	2	1	3	1	2	3
	Skylights	3	2	3	2	2	2	1	1	3
Interior Partitions/Doors		3	2	2	3	2	3	3	1	2
Interior Access Floors		1	3	1	2	2	2	1	1	2
Interior Finishes	Wall Finishes	3	3	2	1	1	2	1	1	2
	Floor Coverings	3	3	3	1	1	2	1	1	3
	Ceiling Treatments	3	3	3	2	2	2	1	1	3
Conveyance Systems		3	2	1	2	2	2	3	1	3
Plumbing	Fixtures	2	1	3	1	1	1	3	1	2
	Dist. And Drainage	1	1	2	1	2	1	2	1	2
HVAC	Central Plant	1	3	3	2	1	1	1	1	3
	Air Distribution	2	3	3	2	1	3	1	1	3
Fire Protection		1	1	1	2	3	3	2	1	2
Service & Distribution	Main Power	1	2	1	2	3	2	1	1	1
	Emergency Power	1	3	2	3	3	3	1	1	2
Light'g & Branch Wiring		3	3	3	3	2	1	1	1	3
Communications & Security		1	2	1	3	1	2	1	1	2
Equip. & Furnishings	Oper. & Maint.	1	3	2	1	1	1	2	1	3
	Food Services	2	2	1	1	1	2	2	1	2
	Fixed Furnishings	3	2	2	1	1	2	3	1	2
Special Building Const.		2	2	2	1	2	2	1	1	2
Demolition & Abatement	Bldg Elements	1	1	3	1	1	1	1	3	1
	Hazard Mat.	1	1	3	1	1	1	1	1	1
Sitework - Building Related	Site Prep.	1	1	3	1	1	1	1	2	1
	Landscaping	3	2	3	2	1	1	2	2	3
	Utilities	1	1	1	2	3	2	1	1	2
Other Sitework - Project Related		3	2	1	2	2	2	3	2	2

The GSA Program Goals Matrix in *Facilities Standards for Public Buildings, P-100* (shown above) indicates critical program-system relationships that must be addressed within building systems programming directives to designers

Another example is the need for uninterrupted power supply (UPS) equipment in mission critical (data center) facilities. Requirements for these buildings may be as stringent as 99.999 percent power reliability, which means just five minutes of unscheduled downtime per year. By comparison, typical utility reliability is 99 percent. Commissioning of mission critical power systems, therefore, focuses on ensuring high levels of reliability as well as power quality. A power interruption of only 8.83 milliseconds can shut down or even damage computers.

Routine quality assurance is needed for all building components. Usually the decision to commission specific building systems is made during the design development phase of a project, but may also occur in pre-design as project performance requirements and design intent documentation evolves.

Conduct Key Commissioning Programming Activities

Many design and construction programs execute careful planning and programming that is embodied and encompassed in master plans, building engineering reports, special studies, feasibility studies, and program development studies. Yet, some building programs execute planning and programming only minimally. For commissioning to be successful, programming documentation must summarize or include the owner's project requirements (OPR) that are both general and specific to critical requirements. The OPR is a summary of critical planning and programming requirements and owner expectations that is updated by the commissioning team as the project evolves. If program or mission elements change during the span of project delivery, the OPR should be updated to reflect changes in building performance requirements. ASHRAE Standard 202-2013 (Annex D) and Guideline 0-2013 (Annex J) provides a general format for developing an Owner's Project Requirements (OPR) which includes:

- Project schedule and budget
- Commissioning scope and budget
- Project documentation requirements (submissions and formats)
- Owner directives
- Restrictions and limitations
- User requirements
- Occupancy requirements and schedules
- Training requirements for owner's personnel
- Warranty requirements
- Benchmarking requirements
- Operations and Maintenance criteria
- Equipment and systems maintainability requirements
- Quality requirements for materials and construction
- Allowable tolerances for facility systems operations
- Energy and water efficiency goals
- Environmental and sustainability goals
- Community requirements
- Adaptability for future facility changes and expansion
- Systems integration requirements
- Health, hygiene, and indoor environmental requirements
- Acoustical requirements

- Vibration requirements
- Seismic requirements
- Accessibility requirements
- Security requirements
- Aesthetics requirements
- Constructability requirements
- Communications requirements
- Applicable codes and standards

The Basis of Design (BOD) is a narrative and analytical documentation prepared by the design A-E along with design submissions to explain how the Owner's Project Requirements (OPR) are met by the proposed design. It describes the technical approach used for systems selections, integration, and sequence of operations, focusing on design features critical to overall building performance. An OPR is developed for an owner/user audience while the BOD is typically developed in more technical terms.

Commissioning Specifications Requirements are developed to outline commissioned systems and equipment performance benchmarks, system integration details, submittal requirements for commissioned systems, initial construction contractor inspection procedures, tests, start-up, turnover procedures, owner training, and final documentation requirements.

Systems Manual Requirements — When determining commissioning requirements, it is also important to define documentation needs that will facilitate and support operation of commissioned systems. O&M Manuals are typically prepared by the construction contractor at the turn-over phase of a project, but are often inadequate to fully explain how a complex facility should be operated. ASHRAE Guideline 1.4-2014, Procedures for Preparing Systems Manual, recommends that a "Systems Manual", containing commissioning and commissioning documentation be prepared for commissioned buildings. Systems Manuals should provide all the information needed to understand, operate, and maintain the systems and assemblies. The Systems Manual should be the repository of information on updates and corrections to systems and assemblies as they occur during the Design, Construction, and Occupancy and Operations Phases. A best practice is to develop a Systems Manual Outline simultaneous with selection, design, and specification of the commissioned systems.

Training Requirements — An important element in the commissioning process is ensuring that O&M personnel are properly trained in operation, care, adjustment, and required maintenance of commissioned systems and equipment. O&M personnel must be trained in the knowledge and skills needed to operate a facility in conformance with its design intent. Training needs must be addressed in the early planning stage to inform operating personnel about staffing budgets and hiring, qualifications, O&M contracts planning and procurement, construction contract training specification development and commissioning authority contract responsibilities.

Some owner groups are beginning to task commissioning authorities with operating facilities for up to one year after turn-over to conduct seasonal testing and systems optimization, allowing for an overlap in O&M contract start-up and training.

EMERGING ISSUES

Increased Emphasis on Occupant Security/Security

In the post 9/11 environment, providing occupant safety to visitors and workers in public facilities has been a driving force to deliver and commission facilities with enhanced building safety measures. Commissioning of security systems, advanced IT systems that integrate into security systems, fire life safety systems that are also integrated into IT, and HVAC systems will need addition scrutiny when commissioning. This trend is not expected to decrease, but will likely increase the standard of care necessary in the design and operation of all forms of public and corporate buildings.

Certification Programs and Standards

Building projects are increasingly requiring performance certifications such as LEED, Green Globes, Energy Star, and others. The project team must discuss and decide on certification requirements in planning and design phases so that a commissioning for certifications can be included in the OPR and Commissioning Plans. USGBC has developed additional certification standards for Existing Buildings, Commercial Interiors, Schools, Core and Shell, Health Care, Retail, Neighborhood Development, and Homes.

Ongoing Commissioning

The benefits of ongoing commissioning or monitoring based commissioning (MBCx) are well documented in annual energy savings in studies conducted by many institutions, such as Texas A&M Energy Systems Laboratory. Fewer studies are available to demonstrate the cost benefits of commissioning new construction. However, threats and risks to operational/business continuity, occupant safety, and health and systems degradation and inefficiency often warrant the added expense of ongoing commissioning.

Commissioning

INTRODUCTION

Building Commissioning is a rapidly growing A-E-C Project Management practice that is being embraced by public and private organizations because of its benefits in improved project delivery results.

This section organizes commissioning information, guidance, and resources under three broad principles, including *Determine*, Plan the Commissioning Process, and Document Compliance and Acceptance. It is important to note that all three principles are applied over the life-span of a capital design and construction project, and that it takes a multi-disciplined effort involving owners, design professionals, construction managers, and commissioning providers to achieve optimal results from the commissioning process.

It is important to start the commissioning process early and to bring the commissioning agent (CxA) on board during or before schematic design. This early involvement is critical for the timely and useful development of the Owner's Project Requirements (OPR), the subsequent design team Basis of Design (BOD) and the beginning of the Operations & Maintenance (O&M) Systems Manual. If these tasks are left until later in the process and "reverse engineered" to match the design, their usefulness as catalysts for dialog and quality tracking tools is lost.

Appointing the CxA immediately after the architects and engineers allows the CxA to become familiar with existing programming documents and proceed immediately to the OPR workshop and the development of the MEP and other criterion that match the project needs. When the Systems Manual is started at this early stage, the inclusion of O&M requirements is ensured. The inclusion of O&M in the early stage project programming is the key to the long- term persistence of the energy efficiency and equipment longevity strategies built into the design.

This section provides an overview of commissioning drivers, benefits, goals, and principles and general commissioning guides, standards, and resources.

Definition

ASHRAE Guideline 0, The Commissioning Process, defines commissioning as "a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria". Commissioning is an all-inclusive process for all the planning, delivery, verification, and managing risks to critical functions performed in, or by, facilities.

Commissioning ensures building quality using peer review and in-field or on-site verification. Commissioning also accomplishes higher energy efficiency, environmental health, and occupant safety and improves indoor air quality by making sure the building components are working correctly and that the plans are implemented with the greatest efficiency.

Commissioning is a quality assurance-based process that delivers preventive and predictive maintenance plans, tailored operating manuals and training procedures for all users to follow. Essentially, the commissioning process formalizes review and integration of all project expectations during planning, design, construction, and occupancy phases by inspection and functional performance testing, and oversight of operator training and record documentation.

Benefits

Commissioning assists in the delivery of a project that provides a safe and healthful facility; optimizes energy use; reduces operating costs; ensures adequate O&M staff orientation and training; and improves installed building systems documentation.

Commissioning benefits owners' through improved energy efficiency, improved workplace performance due to higher quality environments, reduced risk from threats, and prevention of business losses. Organizations that have researched commissioning claim that owners can achieve savings in operations of $4 over the first five years of occupancy as a direct result of every $1 invested in commissioning—an excellent return on investment. Meanwhile, the cost of not commissioning is equal to the costs of correcting deficiencies plus the costs of inefficient operations. For mission-critical facilities, the cost of not commissioning can be measured by the cost of downtime and lack of appropriate facility use.

Drivers

Governmental projects commonly employ commissioning because mission critical facilities support essential public infrastructures. Corporations use commissioning on projects to ensure peak performance to positively impact bottom lines and business continuity. Manufacturers use commissioning because of the high levels of environmental controls needed in their processes and to ensure occupational safety in hazardous settings. While projects with special performance needs require commissioning, all projects need some level of commissioning to perform at their best.

In addition to the performance needs of mission-critical facilities, another factor driving demand for commissioning is the desire to obtain certification through the U.S. Green

Building Council (USGBC) Leadership in Energy and Environmental Design (LEED) program and the Green Building Initiative's Green Globes program.

These rating systems have been developed to improve energy efficiency and environmental performance in buildings—and commissioning is a prerequisite for LEED certification and a requirement in Green Globes. A building certified to these rating systems might include highly efficient power and lighting systems, photovoltaic and active/passive solar technologies.

From an owner's perspective, investment in such sophisticated building technologies must be accompanied by rigorous construction quality assurance and performance verification measurement, which are best provided by the commissioning process. Commissioning beyond the basic prerequisite requirement can earn an additional LEED point. Note that the LEED program is transitioning from the 2009 to 2012 versions as this Design Guide is being updated. The Cx requirements in the 2012 version appear to be substantially increased from those in the 2009 version.

Green design helps reduce building costs while providing for a more comfortable indoor environment, research indicates. Investing in green construction pays for itself 10 times over, according to an October 2003 study prepared for a group of more than 40 California government agencies. The study, conducted by the Capital E Group at Lawrence Berkeley National Laboratory with input from a number of state agencies, reflects the most definitive cost-benefit analysis of green building to date.

Commissioning Goals

Commissioning is often misinterpreted to focus solely on testing during the end of the construction phase. However, commissioning is actually a collaborative process for planning, delivering, and operating buildings that work as intended. ASHRAE (The American Society of Heating, Refrigeration and Air-Conditioning Engineers) defines commissioning as "…the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent…

Commissioning begins with planning and includes design, construction, start-up, acceptance and training, and can be applied throughout the life of the building." This definition accurately depicts commissioning as a holistic process that spans from pre-design planning to post-construction operation and can be thought of as a checks-and-balances system. Accordingly, the goals of commissioning are to:

- Define and document requirements clearly at the outset of each phase and update through the process
- Verify and document compliance at each completion level

- Establish and document commissioning process tasks for subsequent phase delivery team members
- Deliver buildings and construction projects that meet the owner's needs, at the time of completion
- Verify that operation and maintenance personnel and occupants are properly trained
- Maintain facility performance across its life cycle

Commissioning Principles

Regardless of the extent of commissioning that is determined as appropriate for a project (Number or complexity of systems commissioned) and the approach utilized (Independent Commissioning Authority (CA), A-E/CA, CM/CA or Owner/CA), there are three overarching principles in the Commissioning Process that begin at project inception and continue through Occupancy and Operations.

Plan the Commissioning Process

Commissioning involves the systematic process of planning delivery team member roles and responsibilities and tasks for all project phases and activities, including review and acceptance procedures, documentation requirements, development and approval of Commissioning Plans, Commissioning Schedules, and Testing and Inspection plans. Planning the Commissioning Process includes identification of special testing needs for unique or innovative assemblies and measures that will assure adequate O&M Training. Key commissioning activities supporting this principle include:

- Establish Goals for Quality, Efficiency, and Functionality
- Establish a Commissioning Approach and Scope
- Establish Commissioning Budgets
- Establish Commissioning Plans
- Establish Commissioning Schedules
- Establish Testing and Inspection Plans
- Develop Commissioning Specifications
- Determine Special Testing Needs
- Establish Re-Commissioning Plans

Document Compliance and Acceptance

Commissioning serves as the historical record of an owner's expectations for project performance throughout the project delivery process. The purpose of commissioning documenting is to record the "Why, How, and What" of key delivery team decisions throughout the planning and delivery process. Commissioning documents the establishment of standards of performance for building systems, and verifies that designed and constructed work meets those standards. Key commissioning activities supporting Document Compliance and Acceptance include:

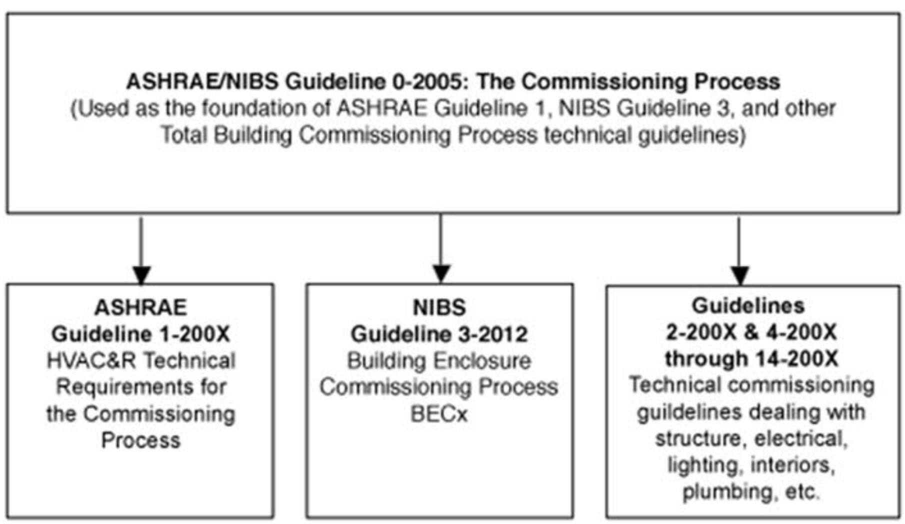
- Document all Levels of Project Development and Acceptance
- Emphasize Inspection, Testing, and Training on Commissioned Systems
- Compile Key Commissioning Documentation

APPLICATION

Currently, no building code requirements exist at a national level for Building Commissioning. However, all new or renovation building programs can benefit from some level of commissioning. Recent case studies conducted in private sector facilities have shown that the Building Commissioning Process can improve new building energy performance by 8% to 30%. Similar results can be expected in other facilities. For complex building types with highly integrated building systems, formal Building Commissioning Processes will provide compounding benefits. Mission Critical Facilities have special needs for protecting their mission continuity and their occupants or building users.

Industry Guidelines

This section of the Whole Building Design Guide is based primarily on the Commissioning Process recommended in *ASHRAE Guideline 0 - 2005*. It is highly recommended that project teams who employ the Building Commissioning Process should follow the process outlined in *ASHRAE Guideline 0*. *Guideline 0* has been adopted by both ASHRAE and NIBS and does not focus upon specific systems or assemblies, but presents a standard process that can be followed to commission any building system that may be critical to the function of a project. The NIBS Total Building Commissioning Program is currently working with industry organizations to develop commissioning guidelines for various systems and assemblies.



NIBS Guideline 3 —Total Building Commissioning (TBC) Process

Conclusion

The commissioning process can be applied in a variety of approaches focusing on building systems/assemblies and can be customized to suit project needs. However, regardless of commissioning approach and system focus, it always requires clear definition of performance expectations, rigor in planning and execution, and thorough project testing, operational training, and documentation.

This section provides guidance on terminology and integrated planning and development processes to establish an owner's expectations for project scope, budget, and schedule. It also provides guidance on managing the team during the planning, design, construction, and occupancy phases of a project.