Total Cost of Ownership - Facilities Management Standard Volume 1

OFFICES OF FACILITIES PLANNING & CONSTRUCTION, BUILDING AND GROUNDS, PURCHASING
Executive Summary

The Total Cost of Ownership of a capital facility includes non-recurring costs such as planning and design, bidding, financing, building and commissioning the project and the cost to decommission, demolish and dispose of the project at the end of its lifecycle. It will also include operating costs through the entire lifecycle of the project such as staffing, janitorial, planned maintenance, unplanned maintenance necessary to make repairs, utilities and the cost of retrofits and improvements over time, modifications to support changing program needs, and the replacement or upgrade of systems as they reach the end of their life-cycles.

Total Cost of Ownership in and of itself is really just a Key Performance Indicator of how cost effective an organization designs, constructs, operates, maintains, upgrades and renovates it’s capitol facilities. The purpose of any Total Cost of Ownership Management Plan is to effectively utilize resources to insure a healthy, comfortable and sustainable learning environment. Implementing strategies, standards and best practices that achieve measureable results is a large part of this process but also, establishing a vision, commitment and a clear direction is necessary to ensure the continued management and care of capital resources for the benefit of future generations.

The idea of generational trust for educational facilities is consistent with the concept of stewardship, to be entrusted with the care of another person’s property or financial affairs or, in the words of Teddy Roosevelt, the buildings and grounds of an institution must be treated “as assets which must be turned over to the next generation increased; and not impaired in value.

Ideally, a statement proclaiming stewardship principles should form the grounding for a comprehensive facilities plan or master plan. Also ideally, facilities stewardship should reflect a broad responsibility of governing board members and senior leaders in addition to the president or chancellor. Today, as the average tenure of a president/chancellor is less than seven years, their decisions must be part of a lengthy, continuous stewardship process, protected because it is an indispensable, shared responsibility.

Facilities stewardship is a high-level and pervasive commitment to optimize capital investments, in order to achieve a high-functioning and attractive campus. It includes a major commitment to capital asset preservation and quality. City College of San Francisco is one of the largest community colleges in the country and has served the educational needs of San Francisco residents for 80 years. Stewardship is about the long view of this institution’s past and future. It forms the backdrop for hundreds of discrete facilities investment and management decisions. Ultimately, facilities stewardship is one of the most compelling responsibilities of institutional leadership.
Total Cost of Ownership Management Standard Volume 1 |

Objectives of this Manual

The purpose of this Volume 1 of this Standard is to provide a foundation for implementing the data processes, procedures, and analytical criteria through planned cost accounting, data sharing and collaborative initiatives that support reduction of the Total Cost of Ownership. This foundation will provide the basis for the development of financial and automated systems that will eventually tie all the data collection points together. The resulting data will inform business decisions that will enhance the support of operational missions with scarce resources. The successful implementation of the process(s) described in this manual will be evident in the reduction of lifecycle cost as demonstrated in the data that will be available to current decision makers.

Deliverables of this Total Cost of Ownership Management Plan Volume 1 are the reduction of capital repairs and costs, unscheduled shutdowns and repairs, extending both equipment life and facility life, realizing life-cycle cost-savings, maintaining a safe, functional systems and facilities that support the college’s mission and providing the proper data for planning, operating, maintaining and staffing the facility(s).

Volume 1 is also describes the various facilities management best practices that occur throughout the life-cycle of our buildings and infrastructure. Many of these best practices are already addressed in the “CCSF Sustainability Plan for Construction, Retrofitting and Operations Part 1 dated December 17, 2009”. This Sustainability Plan presents the guidelines for the long-term development and operation of sustainable campuses to be used as an educational resource for all offices, departments, and Shared Governance bodies and as a guide for all employees involved in planning, design, construction, operations, maintenance and deconstruction activities, and procurement of all materials, supplies and equipment. Part 1 of the Sustainability Plan rests on the Mission Statement of the College and make explicit the intention of the Strategic Plan to meet the needs of the community in a socially, environmentally and economically responsible way.

The Total Cost of Ownership Management Plan Volume 2 will provide phasing, planning, budgeting and scheduling for the full implementation of an integrated facilities management solution.
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1.0 Introduction

“We no longer build buildings as we used to, nor do we pay for them in the same ways. 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.”

As the educational building boom that started in 1998 comes to a close, campus administrators and governing boards statewide are facing the increased financial obligations necessary to maintain and operate expanded facilities portfolios. Most of the school planning and construction of the past decade was allocated to design and construct new buildings to increase capacity and relieve overcrowding. For all of the scrutiny that planning and construction of new educational facilities received, the operational requirements of those new buildings were largely ignored and during that time the deferred maintenance backlog on existing facilities continued to grow. Much of that same pre-1998 inventory is still in use today, with increased repair and maintenance needs, upgrades needed to accommodate new instructional technologies and modern educational programs and, the growing backlog of deferred maintenance.

Now, fourteen years later the state is in a much different place. An economic recession, reduction of available funding and a focus on sustainability have created a need for facilities managers to reexamine traditional facility operations and management. Many campus administrators are discovering that maintaining and operating their facilities require financial obligations of an unexpected magnitude.

Every facilities professional would agree that designing and constructing cost-effective facilities is a desirable outcome that should help mitigate the costs of operating and maintaining those facilities. But

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what is cost-effective building? In many respects that opinion will be influenced by individual interests, objectives and how cost-effective is defined.

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 useful service 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 Total Cost of Ownership.

2.0 Total Cost of Ownership

Adopting a new planning process such as Total Cost of Ownership Management is a commitment to change and improvement. A framework for High-Performance starts with a systematic approach to assessing the current state of the various facilities processes and functions, defining strengths and weaknesses, closing the gap between the current and high-performance state, and enabling a culture of continuous improvement.

Reducing TCO requires the creation of a culture that maintains focus and sustains expectations. To foster a proactive and positive environment, managers must keep the focus on identifying issues, applying effective root-cause analysis, and eliminating the causes of asset-reliability problems. Organizations also can create a structure and systems that promote a proactive approach to maintenance and engineering activities by:

- developing staff competencies
- defining roles and responsibilities clearly
- measuring performance
- providing feedback and counseling
- promoting a focus on quality and precision
- ensuring adequate facilities and resources

3.0 Benchmarking

The plan is to reduce TCO by establishing best practices and measuring results. Leadership, from the top of the organization down to department-level managers, needs to set the expectations across the organizational silos. This process starts with establishing vision, alignment and clear direction, as well as recognizing results. Establish a team approach and collaborated metrics. Reducing TCO requires that
different groups must collaborate. Managers need to establish cross-functional metrics, make sure everyone clearly understands expectations, and tie accountability for metrics into the performance-management system.

Benchmarking is a multiple step process that allows an organization to compare the aspects of performance, identify the differences, seek out alternative approaches, and assess opportunities for improvement, implement the change, and monitor outcomes. It should all begin with an internal evaluation, comparing performance matrices of your own organization over time. In the field of facility management these matrices can include operating costs, space utilization, operations and maintenance activities, moves and facility management staffing.

Benchmarking is used to measure performance using a specific indicator (cost per unit of measure, productivity per unit of measure, cycle time of x per unit of measure or defects per unit of measure) resulting in a metric of performance that is then compared to others. This process is used in management, particularly strategic management, in which organizations evaluate various aspects of their processes in relation to best practice companies' processes, usually within a peer group defined for the purposes of comparison. This allows organizations to develop plans on how to make improvements or adapt specific best practices, usually with the aim of increasing some aspect of performance. Benchmarking may be a one-off event, but is often treated as a continuous process in which organizations continually seek to improve their practices.

3.1 Key Performance Indicators

Of the facility management data published by trade and professional associations for comparing efficiency in the use of facilities, nearly all rely on comparing factors on a per square foot of occupied space or gross area basis. The majority of the metrics used to measure facilities performance are cost-centered; some quality rating metrics do exist. They provide a sound basis for early lifecycle cost advice and the development of lifecycle cost plans. Increasingly, this data is taking on a new importance as the community college system places more emphasis on sustainability and whole life costs.

Annualized Total Cost of Ownership (TCO)/Lifecycle Cost Management: Total cost of ownership (TCO) is a dollar per square foot value ($#/square foot) associated with a facility. It is a calculation of all facilities-specific costs (not including furnishings or non-facility specific equipment) divided by estimated lifespan of the building (30 or 50 years), and the total gross area. Facilities specific costs include all construction, preservation, maintenance, and operations costs. A strategic asset management practice that considers all costs of operations and maintenance, and other costs, in addition to acquisition costs. TCO therefore includes the representation of the sum total of the present value of all direct, indirect, recurring and non-
recurring costs incurred or estimated to be incurred in the design, development, production, operation, maintenance of a facility/structure/asset over its anticipated lifespan. (Inclusive of site/utilities, new construction, deferred maintenance, preventive/routine maintenance, renovation, compliance, capital renewal, and occupancy costs.)

Facility Condition Index (FCI): A comparative industry indicator/benchmark used to indicate the relative physical condition of a facility, group of buildings, or entire portfolio “independent” of building type, construction type, location or cost. The facility condition index (FCI) is expressed as a ratio of the cost of remedying existing deficiencies/requirements, and capital renewal requirements to the current replacement value (i.e., FCI= (DM+CR)/CRV). The FCI provides a corresponding rule of thumb for the annual reinvestment rate (funding percentage) to prevent further accumulation of deferred maintenance deficiencies. The FCI value is a snapshot in time, calculated on an annual basis. Forecasted FCI values for a building in the future, for example, would include the current deferred maintenance items, plus projected values of capital renewal requirements. The FCI is represented on a scale of zero to one, or 0% to 100%, with higher FCI values, representing poorer facility’s condition. While property owners/managers establish independent standards, a “fair to good facility” is generally expressed as having an FCI of less than 10-15%.

Deferred Maintenance/Deferred Maintenance Backlog/Accumulated Deferred Maintenance Backlog: The total dollar amount of existing maintenance repairs and required replacements (capital renewal), not accomplished when they should have been, not funded in the current fiscal year or otherwise delayed to the future. Typically quantified by a comprehensive facilities condition assessment/audit of buildings, grounds, fixed equipment and infrastructure. These needs have not been scheduled to be accomplished in the current budget cycle and thereby are postponed until future funding budget cycles. The projects have received a lower priority status than those to be completed in the current budget cycle. For calculation of facility condition index (FCI) values, deferred maintenance does not include grand fathered items (e.g., ADA), or programmatic requirements (e.g., adaptation).

Facilities Deterioration Rate: Facilities and equipment are in a constant state of degradation. While identified deficiencies/requirements are being corrected, other deficiencies/requirements are continuously being created over time. The rate of deterioration may be expressed as a percentage of current replacement value per year. While degradation rates vary as a function of multiple variables such as building type, current conditions, geographic location, etc., a benchmark deterioration rate for a reasonably well maintained facility is approximately 2.5% per annum. Varying annual capital reinvestments into the physical plant and equipment may alter the degradation rate. The facility condition index (FCI) can be used as comparative metric to help monitor degradation rates.
Deficiency/Requirement (Facility/Structure/Asset): The quantitative difference, typically in terms of dollars amount and associated physical requirements, between an asset’s current physical or functional condition, and an established minimum level of condition/performance. Any problem or defect with materials or equipment.

Recapitalization/Reinvestment Rate: A facility, system, or component with existing deficiencies will deteriorate at a faster rate than a component that is in good condition. The level of annual funding for facility renewal and deferred maintenance expressed as a percentage of facility replacement values. Altering the recapitalization/reinvestment rate has direct impact upon the facility condition index (FCI) and associated deferred maintenance levels over time.

Facility Operating Gross Square Foot (GSF), Index (SAM Performance Indicator: APPA 2003): A strategic asset management practice that considers the yearly costs of facilities operations and maintenance as compared to the APPA Facility Operating Gross Square Foot SAM Performance Indicator.

Custodial Costs per square foot: An asset management practice that considers the yearly costs of custodial labor, materials and equipment.

Grounds Keeping Costs per square foot: An asset management practice that considers the yearly costs of grounds labor, materials and equipment.

Energy Costs per square foot: An asset management practice that considers the yearly costs of gas and electricity.

Utility Costs per square foot: An asset management practice that considers the yearly costs of utilities.

Waste Removal Costs per square foot: An asset management practice that considers the yearly costs of waste management.

Facility Operating Current Replacement Value (CRV) Index: A strategic asset management practice that considers the total cost replace facilities and infrastructure.

4.0 Life-Cycle Cost-Effective Facilities
Currently, the California Community Colleges Board of Governors provides for incentives and funding augmentations to achieve optimum energy utilization, low life-cycle operating costs, and compliance with applicable energy codes and regulations on all new construction, remodeling, renovation, and repair projects\textsuperscript{2}. The California Education Code, Sections 81700-81708 addresses life-cycle cost by allowing a community college district to include life-cycle costs in evaluating Design-build Proposals. The economic incentives to adopt life-cycle cost analysis and other sustainability best practices at the design phase were presented by the Sustainability Coordinator at the California Division of the State Architect who stated that “minimal increases in upfront costs of 0-2\% to support green design will result in life cycle savings of 20\% of total construction costs -- more than ten times the initial investment”.

CCSF has determined that, by focusing on reducing the life-cycle costs of its facilities, CCSF can minimize its Total Cost of Facility Ownership. CCSF incorporates life-cycle cost-effective practices into many aspects of the planning, design and construction processes.

4.1 Life-Cycle Cost in Planning, Design and Construction

The college in the process of establishing design standards that provide clear guidance for the selection of life-cycle cost-effective building systems. The use of design-build construction, requiring facilities that are designed and constructed to Leadership in Energy and Environmental Design (LEED) Silver or Gold facility ratings and adding life-cycle cost-effectiveness to performance-based specifications and proposal-evaluation criteria are opportunities to achieve more energy-efficient, cost-effective facilities. BIM, building commissioning and verification of energy savings may represent design and construction contracting tools available to fully realize promised life-cycle savings.

4.2 Building Information Modeling

Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility that provides a shared knowledge resource and a reliable basis for decisions during its life-cycle; from earliest conception to demolition. Building Information Modelling (BIM) is changing how...
buildings, infrastructure, and utilities are planned, designed, built, and managed and supports the delivery of more innovative, cost-efficient buildings through integrated information and collaboration. CCSF has developed a BIM Standard that is currently in the approval process.

BIM represents a design as combinations of objects, generic or product-specific, solid shapes or void-space oriented (like the shape of a room), that carry their geometry, relations and attributes. BIM design tools allow extraction of different views from a building model for drawing production and other uses. These different views are automatically consistent, being based on a single definition of each object instance. BIM software also defines objects parametrically; that is, the objects are defined as parameters and relations to other objects, so that if a related object is amended, dependent ones will automatically also change. Each model element can carry attributes for selecting and ordering them automatically, providing cost estimates as well as scheduling, material tracking and ordering.

Building Information Modeling (BIM) goes well beyond geometry, spatial relationships, light analysis, geographic information, quantities and properties of building systems, assemblies and components. BIM spans all aspects of the entire building life cycle, including but not limited to Needs Analysis, Capital Planning and Management, Construction Delivery Methods Design, Procurement, Construction, Repair, Maintenance, Sustainability, Renovation, Operations, Space Management, Deconstruction/Reuse. It addresses not only form, fit and function but activities that are traditionally not addressed with 2D or 3D CAD/Visualization.

The California Community College Chancellor’s Office has committed to integrating Building Information Modeling (BIM), Facility Management and Geographic Information Systems (GIS) with the implementation by connecting 71 million square feet of facilities through BIM, FM and GIS using the ONUMA Planning System. The Foundation for CCC is also initiating other open standard systems: Facility Management, Computerized Maintenance Management (CMMS), BAS (Building Automation Systems), EMS (Energy Management Systems) and classroom scheduling that take advantage of this technology.

4.3 Onuma Planning System
The ONUMA system is a web-based Building Information Modeling (BIM) tool. It has been used for years in the design and management of projects and facilities. The ONUMA system is used in FUSION/ONUMA to connect data from the various systems and provide access to data in a graphical format. One of the most powerful features of the ONUMA system is how it manages spatial data. The “Guidelines” place emphasis on how space (room) data is represented and captured in the various BIM/CAD applications to be integrated to FUSION+GIS+ONUMA. That space (room) data is extracted or converted and merged with other data streams to create more intelligent objects to be used in FUSION+GIS+ONUMA.

FUSION (Facilities Utilization, Space Inventory Options Net) is a database of 71-million square feet of California community college facilities that tracks the condition assessments and develops cost modeling for maintenance projects, enabling colleges to plan budgets and help facilitate the passing of much-needed bond measures. FUSION has a consistent classification system for all California community colleges.

The FUSION/ONUMA system presents an opportunity to greatly simplify the use of project data in FUSION. Every CCC district using FUSION has ongoing construction, renovation, and maintenance projects; however, the deliverables from these projects, such as BIM Models, computer-aided design (CAD) or other associated data files, often are not in alignment with the FUSION system. Because of this incompatibility, the data has to be re-collected and manually entered. With the approach outlined in this document, including slight adjustments to standard contract language regarding deliverables, contractor data can now be imported into the FUSION system without the need for manual entry, thus continually enhancing FUSION data. This simplified process will provide tremendous value for the districts, increase the accuracy of facility data, and reduce the cost of maintaining data.

CCSF has initiated the process to implement deployment of the ONUMA/FUSION system. The college will work collaboratively with the California Community College Chancellor’s Office throughout this process.

4.4 COBie2

Currently, most construction documents at California Community Colleges require the handover of paper documents containing as-built plans, equipment lists, product data sheets, warranties, spare part lists, preventive maintenance schedules, and other information that is essential to support the operations, maintenance, and management of the facility by the district. Gathering this information at the end of the job, today’s standard practice, is expensive, since most of the information has to be recreated from information created earlier. COBie simplifies the work required to capture and record project handover data which can be populated directly into FUSION/ONUMA and the College’s CMMS.
The COBie approach is to enter the data as it is created during design, construction, and commissioning. Designers provide floor, space, and equipment layouts. Contractors provide make, model, and serial numbers of installed equipment. Much of the data provided by contractors comes directly from product manufacturers who also participate in COBie. At the early stages of design, the vertical and horizontal spaces that are necessary to fulfill the district's requirements for the building, facility, or infrastructure project are defined. Within these buildings, facilities, or projects are also defined the different types of systems which can include electrical, heating, ventilating and air conditioning (HVAC), potable water, wastewater, fire protection, intrusion detection and alarms and other systems.

COBie data begins with the listing of one or more buildings or projects. If these are buildings each has one or more floors and within each floor there are spaces which will have room numbers. Outside the building, spaces can be referenced by function, such as parking lot or patio seating. COBie allows the two-way exchange of space function, area calculations and other information between ONUMA/FUSION and the designers' CAD or BIM software. Digital information in IPPs and FPPs created as part of the capital outlay program and space inventory information refined during the design process is readily available to project stakeholders and retained in the ONUMA/FUSION site as well as at the districts.

As the design progresses the material, products, and equipment needed for the building are specified. The types of products are most often displayed as finish, product, and equipment schedules. The use of these schedules for any variety of reasons, including quantity take off, asset management, and of course facility maintenance and operations requires multiple, error-prone manual transcriptions.

The types of equipment are listed along with the specific location of each of these types. Product's properties are listed as COBie common attributes. With these data structures, COBie transfers schedule information from designers to builders and later to operators. Information within the COBie file allows the designer to identify fixed or movable property. Components are organized into systems that are also listed in COBie. These systems provide specific building services to building occupants such as alarms, electrical, fire protection, HVAC, plumbing systems, and others. Currently an optional COBie set of data are the connections between equipment. Connections allow the designers to specify how specific pieces of equipment are logically connected. This would allow, for example, a worker to know what other equipment would be effected if a valve closed or an electrical circuit de-energized.

During the design there may be documents of interest pertaining to specific parts of the building. These documents can be linked by reference to the COBie documents data. Designers may also specify the requirements for documents in COBie. One of the most common lists of required documents is the
submittal register. The submittal register is a key aspect of COBie since it is the approved submittals during construction that comprise the bulk of construction handover data sets.

As the project progresses from design to construction, the next stage of the project that contains COBie data occurs when the contractor provides submittals for the designer specified required documents. COBie information exchange allows electronic copies acknowledged or approved submittals to be directly linked to specific types of materials, products, equipment, and systems within the building. The majority of these linked documents are provided as PDF files from documents already created by product manufacturers. Shop drawings should be lined in their native CAD/BIM formats as well as in PDF-views. Scanned or photographic images are required for submittals that require physical samples. When the COBIE data is transmitted these files are provided with the COBIE file on a COBIE data disk.

Once the equipment is installed and tested, the systems are turned on and made operational for O&M staff. In COBie, there are several documents that describe system operations. These documents include Instructions, Tests, and Certifications. As with all other submittals COBie documents are provided in native or PDF format and referenced in the COBie Documents data set.

### 4.5 Cost Management and Building Economics

Cost Management is typically concerned with the initial 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 the district, end-user, and design team being completely unsatisfied with the results. It is important to apply adjustments for factors which affect construction costs, size of the project, renovation versus new, location, 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.

Economic analysis is the monetary evaluation of alternatives for meeting a given objective. For example, to meet the need for additional classroom space one 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).
Life-Cycle Cost Analysis (LCCA) is a cost-effectiveness study that has been used for the comparison of building projects or for the evaluation of energy and water conservation measures. Life cycle costs should include all costs of building ownership over its service life, including construction, maintenance and operations, 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 is an 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. Value Engineering is the elimination or modification of anything that adds costs without contributing to the program’s functional requirements. Reductions in a project's scope or quality to get it into budget are simply cost cutting, not Value Engineering.

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

5.0 Life-Cycle Asset Management

City College of San Francisco has a space inventory of 2,111,436 square feet and in fiscal year (FY) 2013, will have spent over $10 million operating and maintaining those facilities. These expenditures represent the operational components of life-cycle costs which include energy and water, operations, janitorial, maintenance and repair costs. To date, the college has allocated $41 million, or $19.42 per square foot, of GO Bond funds for Capital renewal/reinvestment. These Capital renewal/reinvestment expenditures address energy management and accessibility issues. The current FUSION deferred maintenance backlog, subject to verification, is $218 million or $103.25 per square foot. The current Capital renewal/reinvestment need is $119 million or $53.40 per square foot.

Currently, other than the FUSION Facilities Condition Assessment module, there are no mechanisms in place to identify and quantify the backlog of deferred maintenance or the long-term cost of maintaining
and operating the college’s facilities. CCSF recognizes the need to establish best practices that recognize the environmental, economic, and social benefits of resource efficiency and sustainability; that maximize the life of the facilities and delay their obsolescence and; to provide for a planned program of repairs, improvements and restorations to make them suitable for organizational needs.

A Life-cycle asset management consists of two components; a task plan and a funding plan. The task plan is of distinct value to Building and Grounds personnel in identifying the specific tasks which must be undertaken to improve the condition of the facility. The funding portion of the plan is of value to management in planning for and justifying future funding requirements.

The deferred maintenance reduction plan derives directly from specific deficiencies. By grouping deficiencies by priority and building sub-component for example, a number of individual tasks can be packaged into a manageable piece of work for staff or contractors.

The funding plan will normally incorporate deferred maintenance and component renewal costs. Preventative maintenance costs and any known future functional upgrading costs can also be included if appropriate.

The Life Cycle Asset Management model is a simple but effective tool for managing the future condition of a facility. It can be applied to new or older facilities and can usefully be applied to all district buildings and campuses. The concept of the facility condition index allows buildings, areas within buildings, components or sub-components to be prioritized. This is of particular value in making decisions as to where limited funds should be spent.

Life Cycle Asset Management is best utilized as part of the computer-aided facility management CAFM system and interoperable with the CMMS and FUSION/ONUMA software.

5.1 Capitol Renewal

Capital renewal is the planned replacement of building subsystems such as roofs, electrical systems, HVAC systems and plumbing systems that have reached the end of their useful life. Many of the buildings at CCSF that may serve well in the 21st century already exist but major capital renewal investments are required to replace old, obsolete building subsystems that have reached the end of their lifecycle. Without significant reinvestment in building subsystems, older facilities will fall into a state of ever deteriorating condition and the maintenance and repair costs necessary to keep those aging buildings functional will increase as well. Without due attention, replacement facilities will be required and capital expenditure and resource use will increase unnecessarily.
Typically, using a fixed percentage of the facilities current replacement value (CRV) is an accepted approach to funding facilities renewal budgets. Total current replacement value of all facilities is calculated based upon current published construction costs. The institution then chooses a fixed percentage of the total CRV to determine how much should be allocated annually. In 1989 a report published by the Society for College and University Planning (SCUP) has recommended 1.5% to 2.5% of CRV. Other studies recommend slightly lower ranges of 1% to 2%. A recognized need to incorporate life-cycle cost-effective practices not just into the first costs; planning and construction of facilities but also into energy management, janitorial, operations and maintenance and; future costs including capital investment, capital-replacement, and resale, salvage, and/or disposal costs is necessary to maximize efficient operations and minimize costs.

5.2 Capital (Major) Maintenance/Repairs

The systematic management process of planning and budgeting for known future cyclical repair and replacement requirements that extend the life and retain the usable condition of facilities and systems, not normally contained in the annual operating budget. This includes major activities that have a maintenance cycle in excess of one year (e.g., roof replacement, paint buildings, resurfacing pavement, etc.). The cyclical replacement may be for all or a significant portion (e.g., the replacement of 50% or more of a building system component (lighting system, roof system, etc.) as it reaches the end of its useful life, of major components or infrastructure systems, at or near the end of their useful service life. These activities may extend the useful life and retain the usable condition of an associated capital asset (e.g., replacement of an HVAC system, extending the usable life of a facility). Replacement may be capitalized based on the Governmental Accounting Standards Board/Financial Accounting Standards Board (GASB/FASB) definition. A depreciation model calculates a sinking fund for this maintenance activity. Costs are estimated by a current replacement value that is derived by the California Construction Cost index is developed based upon the Building Cost Index (BCI) cost indices for San Francisco and Los Angeles produced by Engineering News Record (ENR) and reported in the second issue each month for the previous month.

5.3 Deferred Maintenance
Deferred maintenance is defined as maintenance work that has been deferred on a planned or unplanned basis to a future budget cycle or postponed until funds are available. Roof repairs, building component repairs, mechanical equipment, underground utilities, and roads and walkways are projects that are often deferred to the next annual funding cycle. This definition could serve just as well for major maintenance and offers a temptation to bypass the use of annual operating budgets and fund major maintenance through a deferred maintenance reduction program. The difference is that a deferred maintenance program is a comprehensive, one-time approach, often extended over several years, to control a massive backlog of maintenance work.

A facility, system, or component with existing deficiencies will deteriorate at a faster rate than a component that is in good condition. The level of annual funding for facility renewal and deferred maintenance expressed as a percentage of facility replacement values. Altering the recapitalization/reinvestment rate has direct impact upon the facility condition index (FCI) and associated deferred maintenance levels over time.

Deferred maintenance reduction programs result from a campus policy to group deferred major maintenance projects, and sometimes other plant needs, into a program funded separately from major maintenance or capital renewal and replacement.

Major maintenance and deferred maintenance are expenditure programs designed to accommodate the deterioration process of facilities; both programs cope with facilities renewal. As a strategy to achieve funding to eliminate problems of facilities deterioration, deferred maintenance reduction programs can be expanded to include life safety, code compliance requirements, and provisions for accessibility. In contrast, major maintenance is a planned activity of facilities renewal funded by the annual operating budget. Failure to perform needed repair, maintenance, and renewal as part of normal maintenance management creates deferred maintenance.

5.4 Adaptation/Renovation/Modernization

The improvement, addition or expansion of facilities by work performed to change the interior alignment of space or the physical characteristics of an existing facility so it can be used more effectively, be adapted for new use, or comply with existing codes. Includes the total amount of expenditures required to meet evolving technological, programmatic or regulatory demands.
Space modifications to accommodate program needs, sometimes called *program improvements* or *alterations*, are often overlooked in budgeting for facilities needs. It is common to use maintenance funds as the only available source for improvements. Thus, erosion in facilities maintenance results from this practice. A preferred practice is to set up a specific budget line item for functional improvements and to attempt to coordinate major maintenance projects into planning. For example, a revision to a suite of laboratories could include replacements for heating, ventilation, and air conditioning (HVAC); electrical systems; and plumbing systems, creating a project with a larger scope than the space modification project.

### 5.5 Facility Condition Index

The current facility condition index can be accurately calculated using the total estimated cost for all deferred maintenance deficiencies (DM) and the current replacement value (CRV) of the facility. The facility condition index, or FCI, is defined as follows; $FCI = \frac{DM}{CRV}$

Using an accurate Facilities Condition Index and the Current Replacement Value it is possible to model the cost of achieving contemplated future facilities conditions. To provide realistic budgeting of the costs, we must also consider inflation, facility growth, plant deterioration and deficiency deterioration. It should be assumed that existing deficiencies will deteriorate faster than components in good repair.

### 5.6 Facility Condition Audit

The FUSION Facilities Condition Assessment is a good starting point but has some limitations. A comprehensive inspection of the facilities by a multi-discipline team should be considered essential to provide appropriate planning information and accurate benchmarking. The team should include architects as well as structural, mechanical and electrical engineers. The inspection team can be district personnel, consultants, or a combination. Having developed a database of deferred maintenance deficiencies and future component replacement, it is then necessary to estimate the cost, in current dollars, of repairing these deficiencies, or replacing the equipment or systems.

The data regarding the deferred maintenance should include identification of building component and sub-component; a sequential reference number and deficiency rating, location and description and, a deficiency repair cost. Future component renewal costs will be allowances rather than specific costs.

### 6.0 Maintenance and Operations
6.1 Preventive Maintenance

Preventive Maintenance consists of a series of maintenance requirements that provide a basis for planning, scheduling, and executing scheduled maintenance, planned versus corrective for the purpose of improving equipment life and to avoid any unplanned maintenance activity/minimize equipment breakdowns. These can be defined through a Maintenance Plan (MP). PM includes adjusting, lubricating, cleaning, painting, and replacing minor components. Time intensive PM, such as bearing/seal replacement, would typically be scheduled/planned for regular plant or 'line' shutdown periods.

6.2 Maintenance Plan

The purpose of a Maintenance Plan is to describe the best means to maximize equipment operational availability, while minimizing equipment downtime. Once developed, the MP will typically identify PM task descriptions and schedules, troubleshooting, corrective maintenance (repair) task descriptions, and spare parts identification, stock (quantity), and any unique storage requirements. This information will be incorporated in the manual, both as tabular data and text.

Preventive maintenance (PM) data includes equipment tag information, procedures, replacement parts, special tools, lubrication requirements, service providers, warranty information, etc. It is often presented in tabular format in the O&M manual. With BIM implementation, this data can be initially entered via Construction Operations Building information exchange (COBie) between the design construction and operations phases of a project, then transferred to (versus input directly into) PC-based Computerized Maintenance Management System (CMMS) or Computer-Aided Facilities Management (CAFM) software applications.

The collection of data can start early in the process as it has been identified that up to 48% of the data is available at the 100% design phase. Stretching out the process avoids the tsunami of information at handover. The BIM should be used for commissioning then the information can be provided immediately for use for O&M the day the facility opens. Using the National BIM Standard-United States™ open information standards will help ensure you are not locked into any one vendor and you can use any product that supports the open standard for BIM.

CMMS/CAFM applications typically support facility management needs associated with personnel, leasing, furniture, construction, equipment (including fleet vehicles), labor, spare parts inventory (with bar coding), PM scheduling, Work Order generation, and associated costs tracking. There are literally
hundreds of these applications available today, which can be evaluated to identify the most appropriate. The CMMS/CAFM products should have the ability to be tailored to Owner-specific requirements.

6.3 Operations and Maintenance Manual

O&M Manuals provide procedures to operate and maintain a facility's various systems and equipment. It is important to analyze and evaluate a facility from the system level, then develop procedures to attain the most efficient systems integration, based on as-built information and the Maintenance Program philosophy.

The O&M Manuals should be prepared on a System-Level format as follows:

Introduction: Introduces the reader to the facility. Outlines the structure, content, how to use the manual, and includes a brief outline of the various systems covered. In addition, this chapter contains a list of emergency contacts and a list of supplementary material available on the facility such as:

1. Design/Construction Specifications
2. Submittals File
3. Completion Report
4. As-built Drawings
5. Materials List
6. Certified Tests and Reports
   a) Civil/Sanitary
   b) Mechanical/HVAC
   c) Electrical
7. Safety Data: Safety hazards commonly associated with the operation of system/equipment applicable to the facility are identified and their prevention is discussed.
8. Utility Systems: Discusses the various site utility systems that interface with the facility. These include water supply systems, sanitary waste, electrical, natural gas, communications, security, and storm water, etc.
9. Building Interior & Exterior: Includes housekeeping and general maintenance of the facility. The importance of conduction and annual inspection is discussed together with record keeping forms for conducting the inspections.
10. Plumbing: O&M of the domestic water and sanitary waste systems.
12. Heating, Ventilating & Air Conditioning (HVAC): O&M of the building's HVAC systems, including automated controls and exhaust, space heating, and central air systems.
13. Fire Detection & Intrusion Alarms: O&M of fire detection and intrusion detection and alarm systems (wet/dry pipe sprinkler).
14. Electrical: O&M of power distribution equipment and backup/emergency electrical systems (uninterruptible power supply, generator).
15. Conveying Systems: General information and preventive maintenance for elevators, escalators, wheelchair lifts, conveyors, etc.
16. Other Systems Based on Facility Requirements: General information and preventive maintenance requirements for other systems and equipment not already identified.
17. Operating Logs: General information and instructions for using maintenance log forms. A listing of maintenance tasks with their recommended frequencies of performance is included.
18. Maintenance Charts: Maintenance charts include maintenance frequency checklists, maintenance summary, lamp replacement data sheet, equipment data sheets, recommended maintenance and service contacts, and a recommended work order form.
19. Manufacturers’ Literature: Identifies manuals, cut sheets, etc., from equipment manufacturers that amplify information provided within the system-level O&M manual. Manufacturers’ literature generally provides procedures to operate, maintain, troubleshoot, and repair specific items at the equipment level. This information is contained in a separate volume of binders, identified by facility/system, for easy reference. Specific material or complete documents can also be electronically scanned for its 'on-line' use, such as linking from the system-level manual.

System-Level O&M Manual Technical Content/Description

1. Description - System-Level: Description of the system and its purpose, how it operates, and any interfaces it may have. A table can provide overall system design criteria, i.e. flow, pressure, temperature, capacity, power requirements, etc.
2. Operating Procedures - Controls/Start-up/Shutdown/Emergency Over-Ride/Seasonal Changeover: Operating instructions include equipment configurations for each mode of operation, e.g. valve positions, control settings, intended operating strategies, and break-in procedures.
3. Problems and Solutions - Troubleshooting: System-level troubleshooting tables guide maintenance personnel, via fault tree analysis, in a sequential, step-by-step isolation of a system problem to identify faulty equipment. Typical malfunctions, tests or inspections, and corrective actions or recommendations to correct malfunctions are included.
4. Preventive (Planned) Maintenance (PM) - Procedures/Intervals: Maintenance tasks are developed for equipment that comprises the system. Preventive and corrective maintenance is discussed. Scheduled intervals (e.g., daily, weekly, monthly, etc.) are determined and assigned to PM tasks to maximize systems run time, thereby reducing corrective maintenance tasks.
Figures/Illustrations

Operation-/ maintenance-significant figures/illustrations should be included in the manual and referenced from the narrative text. Illustrations can provide the layout of the overall site-campus/facility/floor down to systems/equipment and area/room locations. They can be generated for O&M Manual use from BIM/3D models and engineering drawings that are modified for ease of readability in the manual. They typically include the following:

1. Area floor plans with system/equipment tags and physical (room) locations identified.
2. Safety warnings and cautions regarding potential hazards, both to personnel and to equipment.
3. Photographs of systems/equipment with identifying callouts.
4. Electrical schematics, piping diagrams, air flow schematics, provide equipment interconnections and are important for troubleshooting.
5. Valve schedules indicating valve number, location, type, size, normal position, and description.

Electronic Formats

The elements of narrative text (pdf, html, xml, etc.), graphics including BIM, sound, photographs, and videos can all be organized into a user-friendly, interactive, stand-alone PC or web-based (e.g., Intranet) application or platform.

For O&M manuals, it is often referred to as the Interactive Electronic Manual (IEM), for training materials, Computer-Based Training (CBT). Similar to this document, text and graphical information is typically linked to related data within the O&M manual, or to external sources such as an Owner's intranet or the internet, accessed by a click of the mouse. One caution relative to linking to internet sources is that of security. The Owner's information technology (IT) department should be consulted in these instances.

Screens can be printed on demand. All information, including text, BIM / 3D models / animations, CAD drawings, illustrations, and digital photographs can be viewed and manipulated (read only) by on-line viewers and can only be modified off-line. Updates/modifications are typically through a configuration management process and formal authorization.

Typical Task Performance based on the owner's SOW/scope requirements and maintenance philosophy:

Perform a review and extract as-built information from engineering data such as the basis of design, specifications, as-built drawings, and submittals, vendor/manufacturer documentation, site visit(s), etc., to prepare a comprehensive facility maintenance plan.

Organize and develop information into a clear and concise system-level O&M manual.
1. Physical Descriptions
2. Functional Descriptions
3. Troubleshooting
4. Preventive Maintenance (procedures and schedules)
5. Corrective Maintenance (repair requirements)
6. Parts Lists
7. Organize and tailor scanned / electronic versions of graphical information (e.g., CAD drawings, BIM/3D models, illustrations, digital photographs, etc.) to support text.
8. Compile warranty information.
9. Compile spare parts lists.
10. Enter pertinent data via COBie for its transfer into the owner's CMMS or CAFM application for use by the operation and maintenance staff.
11. Create equipment-specific O&M information (vendor/manufacturer data) library.
12. Develop training plan, student/instructor guides, presentation materials, etc.
13. Develop IEM/CBT.
Appendices


II. CCSF BIM Standard - Draft

III. CCSF Total Cost Of Ownership Dashboard

IV. 2013-03-12-COBieGuide-Public, Dr. Bill East, PhD, PE, F.ASCE, Mariangelica Carrasquillo-Mangual