TOTAL LIFE-CYCLE COST

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Abstract

As designers, we have attempted to look at the life cycle of the building components with varied success. As representatives of facility owners, we need a more comprehensive point of view of the impact that the designer has in the total functionality of the facility over its life. In other words, how does an occupant function within the finished facility? Research has indicated that design can improve workplace productivity from 5% to 35%. Savings of only 3.7% in workplace productivity can pay for the entire facility, including construction, operations and maintenance. What is missing is a holistic facility view as well as the tools necessary to measure and analyze the impact of design improvements on workplace productivity. This can be accomplished using total life cycle costing metrics as well as computer simulation of various alternatives for the workplace being created.

Keywords: life cycle, sustainable design, workplace productivity, simulation, cost estimating, life cycle costing, facility owners

1 The task of expanding the life-cycle

Please discard your previous perceptions of life cycle costing. Total Life Cycle Cost (TLC) is a comprehensive approach to facility cost that focuses on dollars as the primary metric for decisions related to a building to achieve the most effective <u>total</u>

package. Designers must ensure that the functions within a facility are optimized through their design. TLC supports all phases of the life cycle but focuses primarily on occupancy. It provides a single contiguous set of cost tools so that data does not have to be re-entered at each phase of the life cycle and comparisons can be made. It is a complex electronic model requiring tools that take advantage of the latest desktop computing and telecommunications capability. It fully supports current practice but will excel as we move to object oriented design and operations. It is intended for the CEO/CFO of the organization to make strategic decisions as well as to support tactical and operational cost related decisions that involve day to day operations of facilities. The product as described, does not exist today.

Life cycle costing has been a part of the overall cost picture for some time now. Unfortunately it has had little impact on the decision making process to date. Typically the life cycle number is presented in a way that cannot be internalized by the owner. It is not well documented and is presented as a single large number and not as an annualized cost showing peaks as certain items must be replaced over time. Primarily, due to accounting practices, the prevailing attitude seems to be that initial cost issues are here and now and the future will somehow have to take care of itself. Further, it seems that one time initial design and construction costs and the recurring operating costs are not linked. In reality quite the opposite is true. The reality is that the future is now and we have to short change new facilities largely because we can't afford the buildings we designed in the past. This is a Catch-22 situation. The question is how can we break out of this cycle? The answer is that we must expand the original life cycle concept to make it significantly more comprehensive and demonstrate the true impact to the building owner. Only the building owner can pull the industry out of this tailspin. No one else in the building process has as much at stake or can affect the change required in the business process.

Life cycle has traditionally been related to the usable life and cost to maintain various construction materials and pieces of equipment in a building. Recently the concept has been expanded to include the impact such materials have on the environment. While this is a positive step it is still only part of the picture. It still only represents a very small portion of the scope that the designer truly has control over. If misused, the facility might be environmentally correct yet a failure to the owner, based on a poor workplace productivity factor.

There are actually many cycles that a designer can affect in a facility as shown in Figure 1. While there are several items that only occur once in each facility they are repeated by the individual experts on succeeding buildings. Planners, designers and contractors tend to specialize in certain types of projects, because they can take

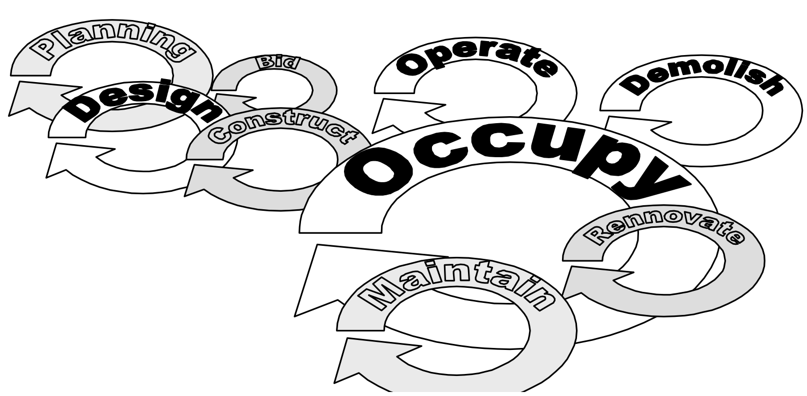


Fig. 1: Various life cycles of a facility

advantage of lessons learned and experience gained. Therefore, they have a cycle they repeat for each facility. Individual facilities also have cycles as employees churn and remodeling occurs or manufacturing processes are retooled. We will examine the relationship of each of these individual life cycles with the total life cycle to include the functions that occur inside the facility throughout its life.

These functions could be mechanical processes as in a manufacturing plant or could be people intensive, as in an office building. A qualitative evaluation of productivity in the workplace must be included in the assessment designers make of the facilities they design. A study done by the Advanced Building Systems Integration Consortium (ABSIC) at Carnegie-Mellon University (Loftness & Hardkoff 1996) indicated that a designer could easily affect productivity by 5 to 35 percent. The study also indicated that improving workplace productivity by only 3.7% could pay for the entire facility. This represents a tremendous untapped potential for improvement. Therefore improving workplace productivity can create essentially "free" buildings. We must collectively foster efforts that target this largely untapped resource.

In order to accomplish this we must have a comprehensive cost analysis tool, something that the industry has not seemed to be able to come up with to date. There have been products over the years that make claims to be comprehensive, yet in reality they still only address a small part of the issue and even those limited scope products have not proven to be fully functional. They end up being black boxes that professionals have trouble trusting.

This paper promotes a total life cycle approach that supports contiguous cost information throughout the entire life cycle of a facility from concept design through occupancy and ultimate demolition. In order for this concept to work, each professional throughout the process must view his or her contribution as only one step along the way in total support of a facility. Information is gained from the professionals that worked previously on the project and the information they collected should be made available to the next professional along the path. A feedback loop must be built in so that constant improvement can occur. This information centric approach was originally portrayed in the Installation Life-cycle Management (ILM) philosophy. However, this proposal primarily focuses on the cost aspect (Smith 1997).

In many instances, such as industrial plants, college and university campuses and military installations, the owner of the facility has to make decisions based on the status of many facilities. The concept proposed is to provide the capability to allow the information from one facility to be combined with other facilities to analyze the entire "campus" or installation. This information centric approach versus a project centric approach has significant potential for making more learned decisions. TLC does not require any additional data collection. In fact it will eliminate a significant amount of redundant data collection. Campus management requires one to know if all the chillers or roofs need to be replaced at approximately the same time so that resource leveling can occur to ensure that all the expense does not need to be absorbed by one year's operating budget. Anticipating or predicting the peaks will reduce the risk that systems will fail unexpectedly which creates crises, typically inconveniencing the occupant and negatively affecting productivity. The decision process can be greatly aided by having specific information about the age and condition of the roofs in order to correctly prioritize the replacements. Cost is the key facet of that decision. Not just the cost of replacement, but also productivity impact cost, or the effect that not doing the project, or the ability to time the project to minimize the negative impact on productivity. This approach will help move one away from a crisis management mentality to planned maintenance. As confidence is gained in the product, the need for a crisis to bring action will diminish. Another reality even more pronounced with today's economy is assessing the impact of delaying repair or replacement. It is normally much less costly to maintain and repair versus replace. The old adage related to changing the oil in one's car should come to mind here – "pay me now or pay me later." The problem is that paying later is a significantly more costly endeavor.

Having energy utilization information available can also indicate when things need to be replaced or modernized. Although the final form of energy is heat, the metric is dollars. Does historical energy usage information indicate that replacement of windows will actually obtain the energy reductions claimed? If you don't have factual information you can only make decisions based on anecdotal hunches. Our goal is to develop a better way.

2 Why the tools do not exist

This is certainly not a new problem and on the surface it is incomprehensible that we don't have some holistic cost analysis tools already available. In discussing this issue with several providers of cost estimating products, it is easy to understand why we are in this predicament. Our industry is very fragmented and there is little communication between the parties involved. The only ones that span all facets of the facilities life, have the most to gain and have the potential to resolve this issue are the building owner. They are the ones that conceive of the project, hire the planner and architect, initiate the contract to build the facility, pay the bills for operation, determine the level of maintenance, decide when to remodel and ultimately decide when to abandon the facility or tear it down. On what basis do owners currently make these decisions? Typically they seek out a professional that is an expert in the specific facet of the overall picture for which their current issue pertains. Those experts provide judgement backed up by tools obtained from software vendors that aid them in answering cost questions for their owner clients. The problem is that they are experts in a relatively narrow field. The providers of the cost tools focus on supporting just one or two of the life cycle facets based on demand from their customers. Figure 2 indicates the relative importance with which each player in the facility life-cycle process views cost. As you can see the only one that has interest throughout is the owner. Every dollar spent has a relationship to profit. Which dollars must be spent and which dollars are overhead and should be targeted for elimination must be clearly identified.

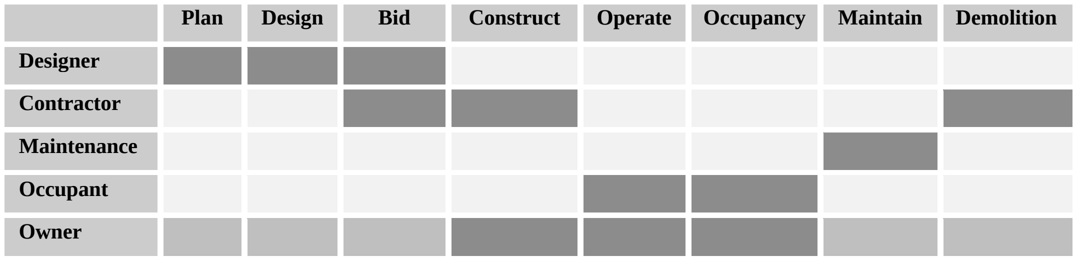


Fig. 2: Level of importance of cost to each participant

The problem with our current fragmented approach is that the big picture is never seen and information has to be recollected at each phase. Due to the cost of data collection only the minimal amount of information necessary to do the job is collected for that phase. Once the information is collected, the report written and the decision made, the process starts over at the next phase with a clean sheet of paper. This leads to significant variances in costs at each phase as well as only snapshots of the entire facilities life cycle cost. Rarely does it take into account productivity, only because no apparent link exists to the expert working on that phase.

One federal agency estimates the cost for new facilities using one commercially available cost database and determines its plant value using another. The problem is that there is a 38% difference between the two databases! How can they expect to make valid decisions concerning the construction of new facilities versus renovating or tearing down the existing facilities? They also have no information at the facility level related to energy costs. The problem is that most of the costs dealt with in one phase are hidden from the others. Not maliciously, but because no one has responsibility for the overall facility. Hence we find situations where steam lines are not repaired because repair dollars are not available while additional steam must be generated due to steam loss. The cost of doing business this way is either passed on to the taxpayer or on to the consumer in higher cost goods. The rare company that does have a handle on this can offer a higher quality product at lower costs and capture a larger portion of their market. Prime examples of this are companies such as USAA Insurance, L.L. Bean and Wal-Mart. Is this then a proprietary or competitive issue? Possibly, but I don’t think that we are that sophisticated. I think it is simply because the costs are hidden and the immensity of the issue and the relationships are not recognized. However, as we see in the Carnegie-Mellon study the two have a major impact on each other and are worth obtaining.

3 The immensity of the problem

The owner is interested in producing a product. The function that a facility serves typically is to house a manufacturing process or people. The primary interest of the owner is optimum productivity and a quality product at a low cost. They may have a handle on the operations of their company, but constructing new facilities is viewed as a necessary evil that takes too much time. It is rarely viewed as an opportunity to improve the company’s bottom line by improving long-term productivity. Our goal is to highlight that the initial facility expense is an investment in the future and ensure it is seen as an asset. Just like investing in the stock market the quality of the stock is a major factor when related to its return and long term growth.

Optimum productivity in the public sector translates into meeting mission requirements within budget. The designer's primary interest is providing a functional facility to the owner. The problem is that the facility itself only represents a very small portion of the cost of providing the function, yet it will have immense impact on the product in the long run.

Figure 3 takes a snapshot of 100 square feet in an office building and assumes that one person occupies that space. Design, construction, operation, and maintenance represent only 5% of the life-cycle cost yet occupies most of the designer's time. In the case portrayed in Figure 3 the personnel costs represent over 95% of the cost of the facility (Rutherford 1997). This is also true in manufacturing where the value of the product produced must dwarf the cost of the production equipment and the enclosing facility in order to turn a profit. The military has a similar example when they build a $5M hangar to house a half billion-dollar airplane. The fact that the design fee represents less than a tenth of one percent of the TLC is not meant to minimize the importance of the facility or the designer, in fact it is quite the opposite. That relatively small investment in a quality TLC designer may make or break your company, although it will be hard to pin the demise on that factor alone. I contend that it is probably the most important factor. Conversely, having an optimum facility that supports high performance workplace and productivity can still fail with poor management. It still comes down to how you use what you have. If you have an optimum facility and you get the most out of it you will have an easier time obtaining a significantly higher level of success.

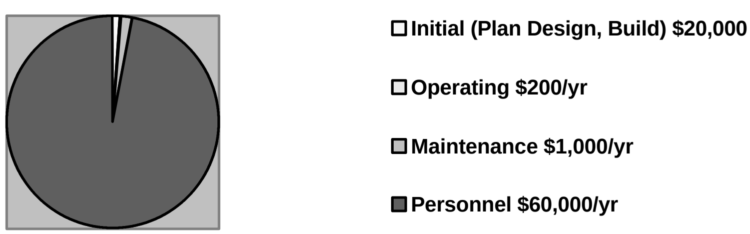


Fig. 3: Functional costs related to facilities (100 SF over 30 years)

Therefore optimizing the design fee at the expense of workplace productivity improvements is extremely misguided. Improving operating costs and reducing maintenance costs do not have as much impact as design issues oriented toward people and improving their productivity.

Actually improving the air quality and lighting and such things can improve both operating costs and productivity because people are healthier and stay on the job longer so win-win situations can be achieved.

If we assume the productivity rule of thumb that one must produce 2.5 times their direct salary, or $150,000 in this case, and if we use the productivity improvements identified in the Carnegie-Mellon study on the figures presented in

Figure 3 improvement in productivity translates into $7,500/person/year at the low end and $52,500/person/year at the high end. Over the 30-year life of the building that could be $1,575,000/person.

The argument for working close to a job site, or even at home, is also a strong one since a one-hour commute in the morning and at night equals a 40-hour week per month! Reducing the commute improves one's quality of life. Hence the adage location, location, location could translate into a primary key to success. If your organization gets an extra week of productivity out of its people by locating close to where they live, it might just be the edge you need. Even if that 40 hours is spent on their own time they will be happier employees able to produce more while at work. Spending an extra million or two for a piece of property therefore may not be a bad decision. However that must be evaluated in the overall picture. None of these opportunities stand alone yet potential workplace productivity savings are found in all aspects of design decision making.

The designer does have the potential to control the items identified in Figure 4. Figure 4 identifies over a dozen items that must be taken into account when looking at workplace productivity. Most are routinely looked at from the initial cost aspects but rarely are they looked at from the productivity point of view. This is mostly because the designer does not have the tools to make productivity related decisions, or the training. Either the data must come from owners or research most likely paid for by owners.

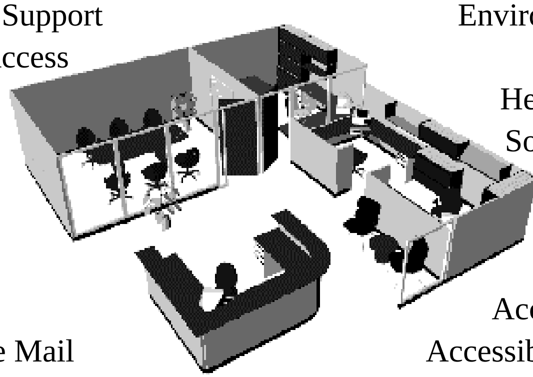
Unfortunately, most projects do not take all this into account in a holistic approach. Often this is because we have little data to support one choice over another. In many cases it is more expensive initially to provide individual temperature controls or enclosed offices. But as you can see from our example in Figure 3 even doubling the initial cost of the space would have little effect on the overall outcome. In many cases providing enclosed offices with sensors to tell when they are occupied will save significant energy costs as lights can be turned off and temperatures can be lowered. This points out the need for expanded workplace productivity studies such as the ones being carried out by ABSIC.

Many of these issues are incorporated into new policy that is being heralded by the White House. The concept of Sustainable Design (Emmons 1998) takes into account the impact that building materials have on the environment. Not only the initial impact, but also the impact of their manufacturer, usage and disposal. This concept is now policy at the Naval Facilities Engineering Command thanks to the efforts of Mr. Terry Emmons.

We are making progress in moving beyond the traditional life-cycle issues with work being done at the National Institute of Standards and Technology (NIST). The work being done there by Barbara Lippiatt on the Building for Environmental and Economic Sustainability (BEES) model (Lippiatt 1998) demonstrates the impact of using various building products. BEES measures the economic performance of building products by using the environmental life-cycle assessment approach specified in the latest version of the ISO 14000 draft standard. This effort is looking at how we can build with renewable resources and make our facilities friendlier to the environment all around, a factor of large proportions and worldwide impact.

Workplace Productivity Issues
Impacted by the Designer

Access to External Support
Email & Internet Access
Privacy
Initial Cost
Ergonomics
Meeting Spaces
Indoor Air Quality
Computer Access
Telephone & Voice Mail



Environmental Impact
Maintainability
Heating & Cooling
Sound Attenuation
Lighting
Circulation
Energy Use
Access to Windows
Accessibility for Visitors

Projected Improvement in Productivity of 5% to 35%

Fig. 4: Designer effected productivity

Another field of study that can greatly aid the designer in predicting workplace productivity is simulation. The work being done by Carson Benson shows very significant potential, especially on complex facilities (Bensen 1998). Simulation is not the same as visualization. In simulation one can “walk” electronic figures through a facility to indicate places where they would go in carrying out daily business functions. An example would be an emergency room. By simulating the movements of say 100 people potentially based on actual cases you can easily identify choke points or areas that are underutilized. In one such example they determined the need for fewer interview rooms and more examining rooms due to predicted backlogs. These are workplace productivity issues.

All these efforts are part of the patchwork quilt that we call construction. What is needed is a unifying element and the argument that encourages it to happen.

4 Achieving Results

No one organization or company can solve this issue and produce the comprehensive product required. We have proven that over the last 2000 years. Therefore a different approach must be undertaken. I propose that an international consortium be formed bringing together top estimating firms and experts involved in all the facets of facility cost engineering, planning, design, construction bidding and change orders, operating, maintenance, insurance, lending, etc. The group calling this group of experts together would be the owners. The issues we are dealing with are common to all developed countries in the world and the benefits will be for all. There are some truly outstanding niche products available throughout the world. However none that I know of link together to allow information to flow from one phase to the next all the way from concept to providing analysis to when it is time to demolish. Certainly there are none that look at workplace productivity improvement issues. In some cases planning can talk to design and design can talk to construction but that is about the extent of our collective capability. A working group must be created for the primary estimating phases of planning, design, construction, operations and maintenance. Two additional groups would represent the financial interests of banking and insurance. There should be an information utility group responsible for identifying the data elements and links needed to accomplish the overall goal.

A board made up of ten leading facility owners, government experts and representatives from the college and university community would steer the group.

Funding for the effort would come from pooled resources from the primary beneficiaries, industry and public-sector building owners. Organizations that participated in the development would be able to use the tool at reduced rates based on their investment. Others would have to pay the full usage fee. The usage or license fee would have to be based on fair market value, and that could be fairly significant over time based on validated payback to the end users. The team should be able to accomplish its efforts in less than two years and the total cost should be approximately two million dollars. Most of this expense would be focused on data collection since most of the algorithms already exist. Assuming the ten board members each provided $100,000 and there were 200 additional owners that each contributed $10,000 the funding needed could easily be attained.

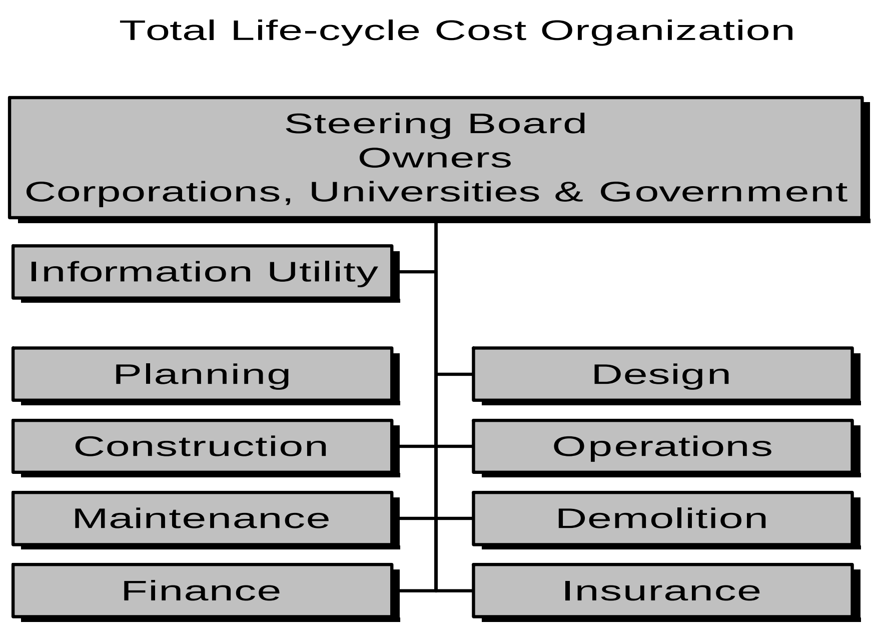


Fig. 5 - Organizational structure

The product must be completely open for understanding by the professionals at each stage. There can be no hidden operations or algorithms. There would be little worry of someone copying the initiative based on the investment and the coordinating effort required. The data could be proprietary and offered by various companies for different portions of the life cycle. Once the product was developed it could be linked to other efforts such as the International Alliance for Interoperability (IAI) and it could easily stay ahead of any competition.

What is missing at this point is a proponent to start the ball rolling. Someone must be willing to invest some time and money to host the groups and provide the logistic support to allow this to occur. The primary candidate would be a large facility owner who would have a lot to gain from having such a product.

5 Summary

In conclusion, it is essential that we produce a comprehensive product that will allow a planner or owner to sketch out a proposed facility and immediately have a rough idea of all of the costs as well as the workplace productivity benefits. This will give them a clear idea of their potential return on their investment. The designer will be able to take that information and develop a design that will accomplish the goals established. The designer will then be able to evaluate alternative designs to ensure that all aspects are optimized. The electronic cost model will ultimately be linked to an object oriented design. The electronic model will be passed to a contractor to provide a bid for construction. An alternative here would be a design build arrangement in which the cost model would be shared as the design develops. Once the contractor is chosen and construction begins final information from the vendors of the products would be included with the model. This information would then be passed on to the operator and maintainer of the facility. Metrics would be monitored to ensure that the facility was working according to design and that the productivity enhancements were being realized. Failures would be made available to the owner as well as a lessons learned database for future projects. Adjustments would be made as needed to enhance the productivity and to ensure that the facility operated as expected throughout its life. As the knowledge base improved the facility could be checked against potential new facilities to see if a new facility would improve productivity and then the old one could be demolished or recycled. All this is possible if we are really serious about improving quality of life and productivity.

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