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Effects of Contract Delivery Method on the LEED™ Score of U.S. Navy Military Construction Projects (Fiscal Years 2004-2006)

Carpenter, Deanna Shane

Monterey, California. Naval Postgraduate School

Effects of Contract Delivery Method on the LEED^{TM} Score of U.S. Navy Military Construction Projects (Fiscal Years 2004-2006)

by
Deanna Shane Carpenter

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Abstract approved ______________________________________
John A. Gambatese

The sustainable development movement in construction has been growing steadily over the last few decades. Many private and public building owners are seeking ways to make their facilities both friendlier to the environment and healthier for the occupants. An added benefit when owners make this choice is lower costs to operate and maintain the building over its life cycle.

The Federal Government has made sustainable development the law for its many agencies and has made significant efforts to demonstrate its leadership in the movement. The U.S. Navy is not only required by law to build its facilities with sustainable features, but it also has its own policy that dictates the exact level of sustainability to be achieved. The Navy has accepted the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) Green Building Rating System as its primary tool in applying sustainable development principles and as a metric to measure the sustainability achieved through the planning, design, and construction processes.

This research study focused on determining the effects that the two major contract delivery methods had on the LEED score of projects over the design and construction time horizon. The Navy uses almost exclusively Design-Bid-Build and Design-Build contracting methods to deliver Military Construction (MCON) projects. Twenty-five projects were analyzed and there were no statistically significant results that could support a conclusion that delivery method adversely or positively affected the LEED score over the project horizon. This result is useful because it encourages the management of Navy construction contracts to look at other areas to increase LEED score rather than delivery method.

Master of Science report by Deanna Shane Carpenter presented on November 18, 2005.

APPROVED:

Major Professor, representing Construction Engineering Management

I understand that my report will become part of the permanent collections of Oregon State University libraries. My signature below authorizes release of my report to any reader upon request.

Deanna Shane Carpenter, Author

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LIST OF ACRONYMS

BD&C……………………………………………………………Building Design & Construction
DB……………………………………………………………………………………Design-Build
DBB…………………………………………………………………………...Design-Bid-Build
DBOM…………………………………………………………Design-Build-Operate-Maintain
DBOOT…………………………………………………… Design-Build-Own-Operate-Transfer
DBOT…………………………………………………………..Design-Build-Operate-Transfer
DD Form 1391……………………………………………...Department of Defense Form 1391
DOD……………………………………………………………………….Department of Defense
DOE………………………………………………………………………Department of Energy
EO………………………………………………………………………………Executive Order
EPA…………………………………………………………Environmental Protection Agency
FACD……………………………………………...Functional Analysis and Concept Design
FEMP……………………………………………………Federal Energy Management Program
FY…………………………………………………………………………………... Fiscal Year
GSA…………………………………………………………...General Services Administration
LCA…………………………………………………………………………Lifecycle Assessment
LCCA…………………………………………………………..……Lifecycle Cost Analyses
LEED™..……………………………………….Leadership in Energy and Environmental Design
MCON…………………………………………………………………………Military Construction
NAVFAC…………………………………………...U.S. Naval Facilities Engineering Command
NEPA………………………………………………………National Environmental Policy Act
OFEE……………………………………………..Office of the Federal Environmental Executive
O&M……………………………………………………………....Operations and Maintenance
PPA …………………………………………………………………...Pollution Prevention Act
ROICC……………………………………………..Resident Officer in Charge of Construction
SpiRiT...……………………………………………………… Sustainable Project Rating Tool
USGBC……………………………………..…………………U.S. Green Building Council
WBDG…………………………………………………………...Whole Building Design Guide

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INTRODUCTION

In 1987, the United Nations World Commission on the Environment (the Brundtlund report) defined sustainable development as "those paths of social, economic, and political progress that meet the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland Commission 1987). This definition is widely accepted as the primary and fundamental description of sustainable development. Federal agencies and private organizations alike use it to set the stage for an integrated and holistic approach to construction and development.

The sustainable development movement has not had a focused path until the late 1990's. The popularity of the phrase "reduce, reuse, recycle", created an opening for any project to be labeled "green" even if only minor modifications were made, such as reusing decorative brick. This "greenwashing" clouded the public's perception of what was truely sustainable development. Several organizations tried to set the standard for sustainable development, but it was not until a consortium of entities created the U.S. Green Building Council (USGBC) that a united and consensus movement was started.

According to its mission statement, the U.S. Green Building Council is the nation's foremost coalition of leaders from across the building industry working to promote buildings that are environmentally responsible, profitable, and healthy places to live and work (USGBC 2005). The USGBC is a consortium of private, public, and educational organizations that over the last ten years have, amongst other things, built a rating system to prevent owners and constructors from "greenwashing" their projects without proper merit. They have also developed Leadership in Energy and Environmental Design (LEED), a voluntary, consensus-based rating system that awards different levels of "green" building certification based on total credit points earned. The design strategy categories and their respective points (out of a total of 69) include the following:

- Sustainable sites (14)
- Water efficiency (5)
- Energy and Atmosphere (17)
- Materials and resources (15)
- Indoor environmental quality (13)
- Innovation and design process (5)

There are four designated certifications: Certified (26-32 points), Silver (33-38), Gold (39-51) and Platinum (52 or more).

The U.S. Naval Facilities Engineering Command (NAVFAC) is one of many governmental organizations required by law to implement sustainable development principles. The legislative foundations for sustainable development are the National Environmental Policy Act (NEPA) of 1969 and the Pollution Prevention Act (PPA) of 1990.

In response to Executive Order 13123, *Greening the Government Through Efficient Energy Management* (1999), a federal task force defined and agreed to a general set of sustainability principles to assist governmental agencies. These principles are closely related to the LEED categories and reach across all environmental areas. They are listed in the Whole Building

Design Guide, a gateway website that provides up-to-date information on integrated "whole building" design techniques and sustainable design strategies and technologies (WBDG 2005). The principles are:

- Optimizing siting potential;
- Minimizing energy consumption while maximizing use of renewable energy sources, to include bio-base products and bio-energy;
- Protecting and conserving water by reducing water consumption, to include recycling water and applying beneficial landscaping practices;
- Using environmentally preferable products;
- Enhancing indoor environmental quality; and
- Optimizing operations and maintenance practices to maintain specified performance levels.

These principles guide NAVFAC in their Sustainable Development Program and are specifically outlined in their Regional Planning Instruction for Sustainable Planning (NAVFACINST 11010.45).

In addition to the above instruction, NAVFAC has instituted a Sustainable Development Policy (NAVFACINST 9830.1) to specifically assign policy, applicability, responsibilities, and actions across the U.S. Navy facilities team. This policy states that "NAVFAC shall use the USGBC's LEED Green Building Rating System as a tool in applying sustainable development principles and as a metric to measure the sustainability achieved through the planning, design, and construction processes" (NAVFACINST 9830.1 2003). It further describes that all construction, renovation, and repair projects costing over $750,000 are subject to the policy in full, whereas projects costing less are to use the sustainable development principles to the fullest extent possible. Projects costing over $750,000 are known as Military Construction (MCON) projects.

An important aspect of the NAVFAC Sustainable Development Policy is the requirement for all applicable projects to meet the LEED Certified level (unless justified mission exemptions exist). NAVFAC requires that projects pursue LEED credits that address life cycle costs, increase operational efficiency, and increase worker productivity in order to reduce the total cost of ownership of shore facilities.

Research Question

Despite policy and instructions that dictate that applicable projects must meet the LEED Certified level, all projects may not achieve this requirement. Several factors may be affecting the projects' ability to be LEED Certified. The projects may not be achieving the Certified level because of mission requirements, site restrictions, timeline expectations, and client/occupant needs. There have also been some changes in the approach to including sustainable first costs in the project estimates. In some previous years NAVFAC required that the planners include the first construction costs as a defined line item in the project budget, while in other years they were instructed to integrate the costs across other line items. This inconsistency could be discouraging planners from achieving the Certified level. The current policy (beginning Fiscal Year 2008), is to submit a completed LEED checklist with the submission of the project conceptual documentation (DD Form 1391).

Additionally, federal funding authorities are occasionally hesitant to pay extra first costs in order to see reduced life cycle costs. According to the NAVFAC Sustainable Planning Instruction (2003), "sustainable design features are weighed against their lifecycle costs and environmental impacts. Historically, the design process has tried to include these features at no overall increase to the project cost, with varying levels of success. Some sustainable design features that would produce long-term savings (lifecycle cost benefits) and would implement good sustainable practices have higher initial costs and could not be added to the construction projects because of budgetary constraints. However, this emphasis on not increasing first costs is changing." The implementation of this final thought varies significantly across NAVFAC.

The Navy uses two delivery methods for Military Construction (MCON) projects. They are commonly used delivery methods, Design-Bid-Build (DBB) and Design-Build (DB). Approximately 60% of MCON projects are delivered via Design-Build. Contract specialists, Civil Engineer Corps Officers, and Project Engineers typically provide MCON project management. Because of the different management requirements for the different delivery methods, projects have varying levels of sustainable features. This research study focused on the differences between DBB and DB with respect to LEED scores over the design and construction horizon.

LITERATURE REVIEW

Defining Sustainable Development

Over time, different organizations have defined sustainable development and its impacts in various ways. The previously mentioned Brundtlund report definition of sustainable development is widely accepted as the primary and fundamental description of sustainable development. Federal agencies and private organizations alike use it to set the stage for an integrated and holistic approach to construction and development.

Sustainable development strives to achieve a harmony between human development and natural systems by integrating the existing built environment with new development within the natural context. The optimal solutions that can meet today's needs without compromising the future availability of resources can be achieved by using a holistic integrated design and construction approach (DOE 2001).

As with most every human activity, there are negative impacts from constructing and operating buildings. These impacts can be severe or slight depending on the attitude of the team involved. The Federal Government can demonstrate their environmental leadership through strong and efficient sustainable development programs. One example is the Office of the Federal Environmental Executive (OFEE). It was created to "promote sustainable environmental stewardship throughout the Federal Government." OFEE's core priorities are waste prevention and recycling, and they are expanding into the broader area of sustainable environmental stewardship (OFEE 2005). OFEE's report, *The Federal Commitment to Green Building: Experiences and Expectations* (2003), stated

"Buildings in the United States have a significant impact on the environment and account for:

- Energy:
    - 37 percent of primary energy use
    - 68 percent of all electricity use
- Material Use:
    - 60 percent of non-food/fuel raw material use
- Waste:
    - 40 percent of non-industrial solid waste or 136 million tons of construction and demolition debris per year
    - 31 percent of mercury in municipal solid waste
- Water:
    - 12 percent of potable water use
    - 36 billion gallons of water per day
    - 20 percent loss of potable water in many urban systems due to leakage."

Because of these sizable figures, it is essential that the construction industry focus on improved materials, methods of development, long term energy use and water consumption in order to reduce the impact of buildings on the environment. The Federal Government can certainly take the lead in this endeavor.

The early implementation of sustainable development can reap large benefits. As mentioned previously, the integrated approach to the design process can bring features to the facility that might not have been considered in traditional design. In its publication titled, *The Business Case for Sustainable Design in Federal Facilities* (2003), the Federal Energy Management Program (FEMP) noted, "To realize the full benefits, sustainable design must begin at the conceptual stage of a project and should be developed using an interdisciplinary team that examines integration of, and tradeoffs among, design features. When the team chooses to include sustainable features, often they can downsize or eliminate other equipment, resulting in lower (or equal) first costs for the sustainable design."

When people internalize the concept that meeting present needs should not compromise the ability for future generations to meet their needs and approach building design and construction with longevity as a primary goal, it is possible for sustainable development to happen. By focusing on lifecycle costs, including reduced energy and water usage, while simultaneously considering first construction costs, a building can be designed and built to meet current needs while giving due concern for the future.

Foundations for Federal Sustainable Development

The legislative foundations for sustainable development come from two major legislative acts. First, the National Environmental Policy Act (NEPA) of 1969 purpose as amended is:

> "To declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man; to enrich the understanding of the ecological systems and natural resources important to the Nation; and to establish a Council on Environmental Quality" (42 U.S.C. 4321 et seq 1982).

And secondly, the Pollution Prevention Act (PPA) of 1990 which is described as:

> "The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner" (42 U.S.C. 13101-13109 1990).

Several federal laws and regulations, including Executive Orders, apply to various aspects of federal agency sustainable planning programs. Executive Order (EO) 13123, *Greening the Government Through Efficient Energy Management* (1999), was designed to significantly improve the government's energy management in order to save taxpayer dollars and reduce emissions that contribute to air pollution and global climate change. It specifically states that, "Agencies shall use lifecycle cost analysis in making decisions about their investments in products, services, construction, and other projects to lower the Federal Government's costs and to reduce energy and water consumption. Where appropriate, agencies shall consider the lifecycle costs of combinations of projects, particularly to encourage bundling of energy efficiency projects with renewable energy projects. Agencies shall also retire inefficient equipment on an accelerated basis where replacement results in lower lifecycle costs." Additionally, EO 13123 dictates, "Department of Defense (DOD) and General Services Administration (GSA), in consultation with Department of Energy (DOE) and Environmental Protection Agency (EPA), shall develop sustainable design principles. Agencies shall apply such principles to the project siting, design, and construction of new facilities. Agencies shall optimize lifecycle costs, pollution, and other environmental and energy costs associated with the construction, lifecycle operation, and decommissioning of the facility." EO 13123 is the driver behind all Federal agency sustainable development programs, including the U.S. Navy's.

The laws mentioned previously state that the Federal Government shall protect the environment, prevent pollution, conserve water and energy, and consider lifecycle costs when conducting business. Combined, these efforts can be reasonably termed "Sustainable Development". Because the Federal Government is so large, it can quickly influence the public as well as the private sustainable movement by implementing efficient, effective, and well-developed programs supporting sustainable design and construction.

Leadership in Energy and Environmental Design (LEED) Rating System

The U.S. Green Building Council created the Leadership in Energy and Environmental Design (LEED) Green Building Rating System to:

- define "green building" by establishing a common standard of measurement;
- promote integrated, whole-building design practices;
- recognize environmental leadership in the building industry;
- stimulate green competition;
- raise consumer awareness of green building benefits; and
- transform the building market" (USGBC 2005).

LEED primarily provides a comprehensive framework for evaluating building performance and meeting sustainability goals. LEED emphasizes state-of-the-art, and scientifically founded, strategies for sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. And finally, LEED promotes expertise in green building through a comprehensive system offering project certification and practical resources, and also recognizes achievements with professional accreditation and training (USGBC 2005).

The LEED design strategy categories and their respective credit points (out of a total of 69) include the following:

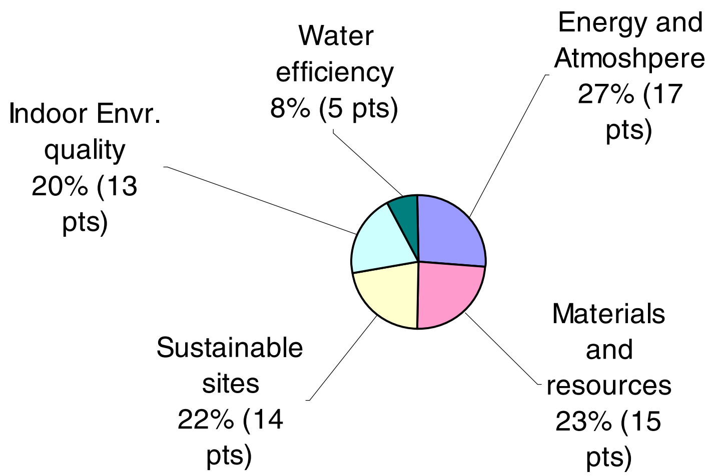

Figure 1. LEED Categories and Credits

An additional five credit points are available in an Innovation and design process area. There are four designated certifications: Certified (26-32 points), Silver (33-38), Gold (39-51), and Platinum (52 or more). A project earns points/credits using a scorecard as a guide. Each design strategy category has multiple credits possible and each has specific requirements that must be met in order for the credit to be earned. For example, for the credit of "Alternative Transportation, Bicycle Friendly" (under Sustainable Sites category), the project team must provide site drawings that highlight bicycle securing devices and changing/shower facilities and include calculations that these facilities will accommodate 5% or more of the building occupants (USGBC 2005). So a project team must actually provide evidence that a particular feature is included in the facility before USGBC will award credits.

The current version of LEED being used to rate New Construction by industry participants is Version 2.1. USGBC has issued various other rating systems for different types of construction, including Existing Buildings, Commercial Interiors, and Core and Shell Projects. A sample scorecard for New Construction is provided in Appendix A.

Many private and public building owners are seeking LEED certification. There are projects in every state and several other countries certified "Green" by the USGBC (USGBC 2005). There are 238 projects that have earned Certified level or better in the United States to date (USGBC 2005). Yet there are still more sustainable buildings being constructed without the LEED Certification. There are two main reasons for the lack of official certification. First, there is a cost associated with having the USGBC certify the project, and in some cases owners do not desire to pay this extra cost in order to have the project "LEED Certified" (Gonchar 2005). The designer and constructor may already assure the owner that the project meets the LEED requirements for sustainability, but funds are not available to get it certified. The second reason is related to the time and energy it requires of the Owner/Designer/Constructor to submit the required paperwork to USGBC to verify that the project meets the LEED credit requirements. The iterative process between the Owner and USGBC makes it even less attractive to get officially certified. The certification process requires a substantial amount of time to prepare the initial registration request, to document the actions taken for each credit, and to interact with the USGBC when disputes arise about the validity of earning a credit.

Although LEED is the primary rating system in the United States, there are alternative sustainable rating systems available. The U.S. Army created a Sustainable Project Rating Tool, SpiRiT, to measure level of sustainability and assist project teams to include various sustainable features in their projects. The rating tool is based on the LEED system, but makes allowances for Army specific design and construction constraints (US Army COE 2005). Internationally there are several resources available to organizations to improve their sustainability. The United Nations Department of Economic and Social Affairs Division for Sustainable Development has ample information available to assist countries to reach a higher level of sustainable development. Also, recall that the widely accepted definition of sustainable development was created at the United Nations. The two resources listed above do not encompass the full extent of sustainable development information available. There are ample websites and organizations that have made sustainable development their mission.

Although LEED is not perfect, the construction industry has adopted it as the standard rating system to measure sustainability. Some project teams have pointed out flaws in the system, and USGBC considers these issues at each revision of the rating system. There is room for improvement, but with any consensus-based initiative, it takes time to implement changes (Gonchar 2005).

An excerpt from the Progress Report on Sustainability (Building, Design & Construction 2004) describes the future of LEED:

> "An even bigger step will be the transition to LEED 3.0, which will shift LEED from being a largely prescriptive system to one that is much more

performance-based. According to Nigel Howard, USGBC Vice President for LEED and International Programs, LEED 3.0 likely will maintain the customary LEED categories — Sustainable Sites, Water Efficiency, etc. — but will provide guidance to the various LEED "product" committees (New Construction, Existing Buildings, etc.) to use performance-based criteria in setting up the credits. Howard expects a draft of this "framework" to be ready by the end of 2005.

LEED 3.0 is expected to address one of the most criticized aspects of the current LEED rating system, its disregard for regional differences. Every architect, engineer, and contractor knows there is a huge difference between building in Miami and building in Seattle due to differences in climate, seismic conditions, precipitation, energy costs, and so on. LEED 2.1 virtually ignores these differences. LEED 3.0 will attempt to introduce a "bioregional rating system" to account for regional differences in climate, water availability, energy factors (cost, type, availability), and other regional differences.

Such a complex performance-based system will require the use of life cycle assessment (LCA). LCA has been defined as "an attempt to evaluate the environmental aspects of a product or a service in a cradle-to-grave-fashion" and has been called "the Holy Grail" of building product evaluation. LCA is crucial to green building because it offers the hope of providing an elegant and definitive way of measuring how "green" a product is. This is especially important to building product manufacturers who want to differentiate their products from their competitors' and who want their products to contribute toward LEED credits.

With those issues in mind, in September 2004, the USGBC convened a meeting of more than 140 individuals representing building product trade associations, LCA practitioners, and environmentalists in Washington, D.C. The theme: "Integrating LCA into LEED."

The USGBC's Nigel Howard set out three requirements for integrating LCA into LEED:

1) The playing field must be level. LCA must be implemented in an objective, fair, and consistent manner.

2) The methodology and data must be consistent, preferably based on the U.S. LCI Database Project Methodology.

3) LCA must be practical and inexpensive to use. While there was widespread agreement on the basics, there was little agreement on a unified approach to integrating LCA into LEED.

Although the intense, daylong meeting ended without consensus, the USGBC's Howard promised to review the findings and report back to the group. Clearly, integrating life cycle analysis into LEED or any

> sustainable design program is going to be a daunting task, one that is likely to take the USGBC, building product manufacturers, and Building Teams well into 2006."

LEED is the accepted measure for sustainability in the construction industry. USBGC is responsive to issues presented by users of the rating system and seeks to continuously improve it. A daunting task for the future is to include lifecycle costs into the system.

U.S. Navy Sustainable Development Policies

The principles from EO 13123 guide Naval Facilities Engineering Command (NAVFAC) in their Sustainable Development Program. These principles are specifically outlined in their Regional Planning Instruction for Sustainable Planning, as previously noted in the Introduction section of this report (NAVFACINST 11010.45 2003).

As one of the many Federal agencies required by law to use Sustainable Development principles in the design and construction of facilities, the Navy has a formal policy for implementation. NAVFACINST 9830.1 (2003) specifically designates which projects are applicable to the policy and who in the organization is responsible for including sustainable features in projects. Most importantly it sets the goal of meeting the LEED Certified level for all applicable projects.

Barriers to Sustainable Development

Although the concept of sustainable development appeals to many in both the Federal and private sectors, there are barriers to full or even partial implementation. These barriers, explained in the following sections, are the Federal Budget conflict, the debate over first construction costs, and how to involve lifecycle costs into the projected overall savings.

Federal Budget Conflict

Current Federal fiscal practices allocate funds for one-time construction and long-term operations and maintenance (O&M) differently. While both amounts are estimated and sent through various budgeting cycles until they are approved or amended, the Congressional group that considers the one-time construction expenditures is not directly involved with the approval process for the O&M expenditures (Candreva 2004). As a result, the requirement to consider lifecycle costs (O&M costs) when designing facilities is challenging to incorporate because the funds come from different parts of the budgets. The Federal Government has recognized this concern. FEMP's document titled, *The Business Case for Sustainable Design in Federal Facilities* (2003) noted that, "Despite the lifecycle costing requirements, government project managers still find it hard to include all of the sustainable design features they would like to see in building projects. Because O&M costs are appropriated and managed separately from capital expenditures (construction), agencies find it difficult within their normal budgeting process to use lifecycle cost analysis, which intertwines capital and O&M into one comprehensive metric. Capital budgets are usually preset for construction projects, so increasing the budget to include the extra cost of sustainable design features is difficult. Interpretations of how lifecycle costs should be considered in government construction projects vary between agencies and even within agencies."

Specifically for the Navy, NAVFACINST 11010.45 (2003) states, “Sustainable design features are weighed against their lifecycle costs and environmental impacts. Historically, the design process has tried to include these features at no overall increase to the project cost, with varying levels of success. Some sustainable design features that would produce long-term cost savings (lifecycle cost benefits) and would implement good sustainable practices have higher initial costs and could not be added to construction projects because of budgetary constraints."

Although the separation between different parts of the Federal budget make it challenging to incorporate sustainable features in facilities because of their sometimes higher first costs, agencies are beginning to realize that these increased first costs may in fact have long term benefits. One way around the conflict is to include the design features at the beginning of the planning process and in the construction budget, incorporating both their costs and benefits.

The Debate over First Costs

There continues to be debate in the construction industry about whether or not designing and building sustainably costs more than conventional methods. In September of 2004, Building Design & Construction (BD&C) magazine hired Reed Research Group to survey a scientifically drawn sample of 10,000 recipients of BD&C via the Internet to determine their opinions, perceptions, and actions related to sustainability. A total of 548 people responded. According to the results of this survey the debate over first costs persists. Despite recent studies reporting that green buildings need not necessarily cost much more to construct than "conventional" buildings, a growing percentage of BD&C survey respondents said clients and prospects objected to any cost premium. When respondents were asked: "Are first costs still seen as the single greatest barrier to sustainable design?," 52% replied that "Sustainability adds significantly to first costs." This same question was asked in 2003, and 44% had the same response (BD&C 2004).

Another related result from the BD&C Progress Report on Sustainability (2004) survey was related to getting proof that sustainable buildings cost the same or are even less costly than conventional buildings. The report states: "For the second year in a row, respondents stated that the missing ingredient that would have an effect in promoting sustainable design was independent analysis of the relative costs and benefits of green buildings vs. conventional buildings." Sixty-two percent replied that they wanted, "Independently validated documentation of the relative costs/benefits of green buildings vs. conventional buildings." Fifty-nine percent had the same response to this question when asked in 2003.

This "missing ingredient" has been identified for the Federal sector. FEMP presented a detailed report confirming that sustainable development does not have to cost more than conventional buildings (FEMP 2003). In the report, FEMP states that, "Many Federal designers and planners embrace the goals of environmental stewardship and social responsibilities, but capital budget constraints often stand in the way of smart design choices. Federal managers need hard facts and figures to help articulate the "business case" for sustainable design. Without clear information about the lifecycle costs and other benefits of design alternatives, Federal decision-makers are likely to continue favoring traditional design choices".

FEMP (2003) went on to say, "A lifecycle approach supports the use of many sustainable design features because the annual cost savings from these features over their lifetimes can offset their sometimes-higher first costs. However, because capital budgets are usually preset for Federal construction projects, government-building designers sometimes find it difficult to increase the capital budget to include the incremental first costs of some sustainable design features. Nevertheless, Federal agencies have found many creative ways to stay within their capital budgets while making their buildings "green". In fact, sustainable design does not have to increase the cost of constructing a facility, and in some cases, may actually lower first costs, as well as operating costs."

Some simple ideas can be incorporated into a facility's design to keep first costs down, and can be particularly helpful when they are integrated early in the design process. FEMP (2003) provided the following design and construction strategies that a team can use to reduce first costs:

- Optimize site and orientation.
- Re-use/renovate older buildings and use recycled materials.
- Reduce project size.
- Eliminate unnecessary finishes and features.
- Avoid structural overdesign and construction waste.

- Fully explore integrated design, including energy system optimization.
- Use construction waste management approaches.
- Decrease site infrastructure.

In addition to these strategies, some materials and fixtures that reduce environmental impact have lower first costs than their traditional counterparts. Implementing some of the sustainable features discussed above (concrete with slag content, recycled carpet, low-emitting paint, certified wood doors, and no-water urinals) can lower the total building cost by about 2% (FEMP 2003).

It can be difficult to convince owners to build a "green" building, especially if they have the idea that it will cost more than a "conventionally designed" building. As the BD&C survey reports, owners do not want to spend more than they have to and they want proof of "green" costs/benefits. Done correctly, sustainable features can be included from the concept of the project and costs can be incorporated early so that they can be budgeted for and the clear benefits of these features can be demonstrated with lifecycle payback periods.

Lifecycle Costs

Just about every consumer weighs the benefits of a well built, long lasting product against its initial cost. The basis for requiring a lifecycle approach to federal building comes from both EO 13123 and the Energy Policy Act (1992). Each of these laws emphasizes the need for lifecycle cost-effective solutions. Specifically, government agencies were asked to compare construction or repair options based on costs over the lifetime of the facility and its equipment, not just on the initial capital outlays. Lifecycle-cost analysis often supports adding sustainable design features because the annual cost savings typically offsets higher first costs associated with these features over their lifetimes (FEMP 2003). NAVFACINST 11010.45 (2003) echoes the concept by stating that sustainable development considerations should be included in lifecycle cost analyses (LCCA) and be used when planning corrections to facility deficiencies. It implores managers to budget for environmental and energy-efficient equipment, systems and design solutions based on LCCA.

Ideally, a sustainable design approach produces both interior and exterior environments that lead to increased human productivity and performance, and better human health. Design measures that increase human production and improve health can be cost effective in the long run because the human resource constitutes the vast majority of the life cycle cost of a facility. As the cost benefits may be difficult to quantify, planners must justify sustainability by evaluating the entire lifecycle of a facility, then integrate sustainability into the budgeting process (NAVFACINST 11010.45 2003).

Required by law to use lifecycle costs to justify the least cost alternative construction project, Federal agencies still find it problematic to strike a balance between the one-time cost of construction and the long-term O&M costs (lifecycle costs). The policies are in place to instruct Federal engineers and planners how to implement sustainable features; the results of these policies are yet to be determined.

Combined Federal Efforts to Support Sustainable Development

To assist Federal agencies in their pursuit of sustainability, various tools and guidelines have been developed. A major contribution was the development of the Whole Building Design Guide (WBDG). "The WBDG is the only web-based portal providing government and industry practitioners with one-stop access to up-to-date information on a wide range of building-related guidance, criteria and technology from a 'whole buildings' perspective. Development and updating of the WBDG is a collaborative effort among federal agencies, private sector companies, non-profit organizations and educational institutions. Its success depends on industry and government experts contributing their knowledge and experience to better serve the building community" (WBDG 2005). Similar to the LEED principles, the fundamental strategies for sustainable design in the WBDG include the following:

- Optimizing site potential
- Minimizing energy consumption
- Protecting and conserving water
- Using environmentally preferable products and materials
- Enhancing indoor environmental quality
- Optimizing operations and maintenance (O&M) practices (WBDG 2005).

These strategies are exactly those presented to articulate the goals of EO 13123. Designers and builders frequently seek guidance from this resource when performing contracts with Federal agencies.

Another resource available to consolidate efforts of the Federal Government is the document titled, *Greening Federal Facilities, Second Edition* (DOE 2001). "It is a nuts-and-bolts resource guide designed to increase energy and resource efficiency, cut waste, and improve the performance of Federal buildings and facilities. This guide highlights practical actions that facility managers, planners, and design and construction staff can take to save energy and money, improve the comfort and productivity of employees, and benefit the environment. The guide is one more step in a national effort to promote energy efficiency and sustainable actions in the nation's 500,000 Federal buildings and facilities" (DOE 2001).

Using a consolidated resource of information regarding Federal project design and management, the WBDG helps distribute information across several agencies quickly and accurately. The additional feature that helps is keeping the information updated and easily accessible. The *Greening Federal Facilities* guide presents practical ideas and technologies to facility managers, planners, and design and construction professionals. The two combined provide powerful resources for the Federal building sector.

Positive Impacts of Sustainable Design

Government efforts to implement sustainable design have potentially significant impacts. For some perspective on how large of an industry the Federal Government is, the following values are presented. The Federal Government owns about 500,000 facilities worldwide, valued at more than $300 billion (National Research Council 1998). It spends over $20 billion annually on acquiring or substantially renovating Federal facilities, and it uses over $3.5 billion annually for energy to power, heat, and cool its buildings (Federal Facilities Council 2001). In addition, the government spends almost $200 billion for personnel compensation and benefits for the civilian employees occupying these buildings (U.S. Office of Personnel Management 2003). Building designs that reduce energy consumption while also providing a healthy and pleasant environment for occupants will result in more cost-efficient government operations and lower environmental impacts that affect the public (FEMP 2003).

Although, some sustainable design features have higher first construction costs, the payback period for the incremental investment often is short and the lifecycle cost is typically lower than the cost of more traditional buildings. Specifically evidence is growing that sustainable buildings provide financial rewards for building owners, operators, and occupants. These buildings typically have lower annual costs for energy, water, maintenance/repair, and other operating expenses (FEMP 2003).

Sustainable buildings can provide indirect economic benefits to both the building owner and society as well as direct cost savings. "Sustainable building features can offer owners economic benefits from lower risks, longer building lifetimes, improved ability to attract new employees, reduced expenses for dealing with complaints, less time and lower costs for project permitting resulting from community acceptance and support for sustainable projects, and increased asset value" (FEMP 2003). Another example is that sustainable building features can promote better health, comfort, well-being, and improve productivity of building occupants. All of these can reduce levels of absenteeism and increase efficiency. Sustainable buildings also offer society as a whole economic benefits such as reduced costs from and lower infrastructure costs, e.g., for avoided landfills, wastewater treatment plants, power plants, and transmission/distribution lines (FEMP 2003).

Federal agencies, as well as sustainable building owners in the private sector, are likely to accumulate economic benefits from a sustainable facility. The environmentally and socially conscious image can have positive impacts on building occupants, prospective employees, the community surrounding the facility, and society as a whole. Several of these somewhat indirect or longer-term economic benefits may include:

- Better worker retention and recruitment
- Lower cost of dealing with complaints
- Decreased risk, liability, and insurance rates
- Greater building longevity
- Better resale value
- Ease of siting
- Strategic and economic value of an improved image (FEMP 2003).

The environmental impacts from building construction, operation, and demolition are many and include air pollution emissions, greenhouse gas emissions associated with climate change, solid waste generation, water pollution, natural resource depletion, and habitat disturbance. Sustainable design aims to significantly reduce these impacts. These improvements will reduce the health effects and costs associated with environmental pollution and will have other less tangible, but still important, economic value to society (FEMP 2003).

The enormity of the Federal facility and occupant figures described above begs for improvement. The benefits and impacts of sustainable development are numerous and can be realized with relative ease. Incorporating an integrated approach to design and including sustainable features from the onset can help capture the benefits.

Delivery Methods for Constructed Facilities

There are several different ways for an owner to design and eventually build a facility. The contracting method used to design and build facilities is called the project delivery method. Delivery methods commonly used in the public sector include: Design-Bid-Build, Design-Build and Design-Build with Variations. The amount of risk, management, and control for each of the project team members (the owner, designer, constructor, and operator) differ for each method.

The most traditional method is Design-Bid-Build (DBB). When using DBB, a project is completely designed by an Architect/Engineer entity and the documents produced from this effort are made available for bids by construction contractors (constructors). This method enables an owner to closely monitor the project and account in detail for expenditures. It is also used if owners are obligated to procure construction services by competitive bidding (ASCE 2000). One feature of this method is that the owner hires a designer and the constructor separately. Having two entities working towards the same goal can provide project benefits and simultaneously be a challenge for the owner.

The DBB system is explained more thoroughly in the American Society of Civil Engineer's manual *Quality in the Constructed Project: A Guide for Owners, Designers, and Constructors* (2000). With the DBB delivery method, the owner defines project goals and objectives, secures the financing, and specifies the standards and contract terms. The design professional then uses the owner's project goals and objectives, the project's site conditions, and sound engineering practices to create the construction bid documents. Prospective constructors use the complete and specific bid documents to prepare their bids. Each contractor typically evaluates risk and uncertainty to identify potential conditions that could affect cost or schedule. The bidders submit their proposals to the owner, who determines the most responsive bid, which is typically the lowest bid meeting the project objectives. The owner enters into a contract with the "low-bidder", who then constructs the facility for the owner.

Design-build (DB) project delivery is when one entity is responsible for both the design and construction. Because DB provides the owner with a single point of contact for project responsibilities it practically eliminates the need to assist in resolving designer-constructor disputes. This feature is very powerful when an owner contracts for construction infrequently. Costs are typically defined and maintained to a greater degree with the constructor playing a major role in design. The design-builder makes many decisions that the owner would make under DBB because the owner delegates greatly increased authority to fulfill an increased number of responsibilities. The owner's ability to accommodate the design-build approach and their comfort with the method both impact the potential benefits and the degree to which they are realized. Compared to DBB contracting, DB involves a significantly different set of requirements and expectations for the processes, timeliness, and communication. The constructor directs issues that affect design, such as constructability, the use of particular equipment or erection methods, the choice of construction materials, and schedules. As such, the focus of the designer's efforts is on meeting the project objectives as planned by the constructor (ASCE 2000).

Some variations of the Design-build arrangement provide the owner more project functions than just designing and building the project. The three main variations are loosely called "turnkey". Turnkey project delivery essentially adds to the design-builder's responsibilities the operation and/or maintenance of the completed project. Projects with limited contractor operation periods are known as design-build-operate-transfer (DBOT). Design-build-operate-maintain (DBOM) project delivery is most often used where the period of contractor operation and maintenance is about 10 to 15 years. The design-build-own-operate-transfer (DBOOT) method is a broader type of turnkey, typically used for a toll road, bridge, or other elements of revenue-generating public infrastructure (ASCE 2000).

Federal agencies, as facility owners, have a limited number but distinct options for contracting for design and construction. Essential to the selection process of both the designer and contractor are the allocation of risk, budget, and schedule. However, regardless of the type of delivery method selected, the agency still has the responsibility to properly manage the contract and receive the very best service the contractor has to offer.

Summary

Not only is sustainable development a good idea for the planet, it is the law for Federal agencies. There are policies and programs in place to implement sustainable practices in the built environment, but somehow Federal facilities are still being constructed without all of the features possible. The previously outlined barriers to sustainable development are, in part, hindering full implementation.

The benefits of sustainable development are many. Facilities designed for sustainability frequently have lower operating costs over their lifecycles and are typically facilities that improve occupant productivity. Additionally, the use of renewable and less toxic construction materials helps the planet.

There may even be other barriers to implementation or more benefits yet to be discovered. It may even be the case that owners just are not interested in saving money in the long run; they just want their building finished on time and on budget. Time will tell if Sustainable Development will remain on the edge of mainstream construction methods or if it will become "the" way to build.

As for the Navy, the law requires sustainable development and there are numerous policy directives that delineate just how to implement it. However, there are still projects that do not include sustainable features. The barriers outlined above affect Navy projects. There may also be an impact on the inclusion of sustainable features by the delivery method used.

RESEARCH METHODOLOGY

There are two goals of this research study. The first goal is to begin the historical data collection efforts required by the Navy's Sustainable Development Program in order to demonstrate its progress over time. The second goal is to investigate how level of sustainability is impacted by various project parameters on Navy projects. To obtain these goals several objectives were developed prior to the start of data collection. The first objective was to collect only the required information from the Sustainable Development team members needed to describe the projects and their level of sustainability. Superfluous information was deemed unnecessary and was not requested. Another objective was to create a data template that would meet the needs of the Program for many years. The idea was to have the template remain the same for each year's data collection efforts. This would assist the team members in keeping the information updated periodically instead of waiting for the data collection request each year. The objective set for the second goal was simple. It was necessary to collect pertinent data that can be used to demonstrate what effects project delivery method had on the LEED credit score over the project horizon.

Background

Some additional information about how the Navy procures new construction projects is presented to help the reader understand the time scale of the process. First, the Navy Facility Planning Process is presented to explain the idea of how a need is developed into a project. Next, a brief explanation of how the Navy's hierarchy affects the planning process is given. And finally, how the Navy's Sustainable Development Program is structured and takes part in the planning process is provided.

Navy Facility Planning Process

Every year Navy personnel perform an inspection of all of the facilities on each Navy base or installation. Besides buildings, these include support facilities such as water treatment plants, utility systems, and waterfront structures. An annual report called the Annual Inspection Summary is created that presents the results of these inspections. From this report, base facility managers can prioritize maintenance, repair, and construction budgeting efforts. Also from these inspections any unmet facility needs can be identified. Another way that a repair or construction project can begin is from a tenant command. The tenant command will approach the Public Works Department with a need for an altered or new facility to meet a mission requirement. When a project is justified to meet either this need or to address issues from the inspections, and the estimated construction cost is over $750,000, the project must be approved by Congress and is sent through the Military Construction (MCON) programming process.

If a base has a need for a MCON project, several steps occur before design and construction can occur. First, the base creates an Activity Department of Defense Form 1391, simply referred to as a "1391", which provides the required scope and a rough cost estimate (NAVFACINST 11010.45 2003). This form is sent to the corresponding higher level Regional command for prioritization and further development. If the project has enough priority, it will make it to Congress for approval and authorization (Thurber 2005).

After Congress has authorized design funds for the project, a Functional Analysis and Concept Design (FACD) is conducted. A team is assembled to develop a more detailed scope and costs for programming and budgeting purposes. This team is composed of many stakeholders, such as base and headquarters planners, designers, project managers, facility maintenance personnel, users, environmental planners, and sustainable planners (NAVFACINST 11010.45 2003). The results of the FACD are used to develop the scope for the design contract, and typically represent completion of about 15% of the design (Miller 2005).

At this point the project is contracted to a private company for completion. Approximately 60% of the Navy's acquisitions are Design-Build (DB) and the remaining projects are Design-Bid-Build (DBB). There are varying levels of oversight by the Navy with these two methods of delivery. During both the traditional DBB method and DB method, the designer must submit many deliverables to the Navy for approval. With DBB, only after the design is complete does the Navy contract with a constructor. However, with DB, the entity has fewer deliverables during the construction phase. The DB entity has much more autonomy during construction (Miller 2005).

Navy Facility Hierarchy

The Navy facility decision-making system is set up as a hierarchy. Starting at the bottom, the installation or base Public Works Department has the most intimate knowledge of facilities and any issues regarding needed changes. Climbing up the ladder, the Regional Command is responsible for many installations or bases, and project knowledge is more general. However, at this Regional level, facility needs are prioritized so that the next higher level is made aware of needs in an orderly manner. Regions from the continental United States and Europe are combined under the Theater Command NAVFAC Atlantic. Regions in the Pacific are combined as Theater Command NAVFAC Pacific. Each of these two Theater Commands reports to a Global Command: Commander, Navy Installations. As is true in any hierarchy, information must be filtered and prioritized as it moves up the chain of command. This is true for the MCON projects too. As a project is developed, it must move up through each of the levels of command and, with each higher level more detailed information is gathered about the project. This detailed information for MCON projects is designed to justify the project's worthiness when it gets to the Congressional level (Orndoff 2005).

NAVFAC Sustainable Development Program Organization and Purpose

In 2003, NAVFAC created the Sustainable Development Program and began the process of organizing a staff to support its mission. Its purpose is to provide guidance and directives related to sustainable development for all Navy construction and repair projects. A Program Director is the lead with a Team Member assigned for each Regional office. The Program Director is responsible for defining all requirements related to sustainable development for NAVFAC projects. This effort is described in general in NAVFAC Instruction 9830.1 and each year the specific guidance is promulgated through the chain of command. Team members, normally NAVFAC civilian engineers or architects, are assigned as a collateral duty to their regular duties. Their responsibilities are to be involved, and act as a sustainable advocate, during the FACD process with MCON projects and to monitor the sustainability features of these projects over the design and construction time frame (Talton 2005).

Data Collection

The data collection phase of the research study was broken down into three main components. First, the types of data required were described and organized. The next phase was to send the data template to the team members with explicit directions and a timeline for returning their information. And finally, the data was collated and any questions were addressed such that the data was consistent across all Regions.

Data Organization

First, a total list of all Navy MCON projects was obtained. This list included the projects' Fiscal Year designation, the Project Title, the Location or Base of the project, and the Region that is responsible for its construction. Three fiscal years (FY) of data were collected. FY04 projects were primarily in the construction phase or completed. FY05 projects were in various phases of design. And most, but not all, of the FY06 projects had completed the FACD.

An Excel spreadsheet was created and with concurrence of Navy's Sustainable Development Program Director, Dennis Talton, RA, various sections within the spreadsheet were developed. These sections were: General Information, 1391 Information, Resident Officer in Charge of Construction (ROICC) Information, LEED Information, and Water and Energy Information. Each section asked for information from various MCON project team members. The sections are described in more detail below, and the entire template, including the notes used in the title cells, can be found in Appendix B.

The General Information section of the template included basic information about the projects, specifically Fiscal Year designation, the Project Title, the Location or Base of the project, and the Region. It further included the following items: Project Manager with phone and e-mail contact, and the Sustainable Development Program Team Member.

The 1391 Information section of the template included the following items: the project's Category Code (a numbered code to describe the exact type of facility), the Size (square meters or square feet), the Project Cost, a narrative description of Sustainable Features, a total Sustainable First Cost (if itemized in the project's budget), and the Delivery Method.

The ROICC Information section of the template asked for the following items: the Phase of the Project (Design or Construction for example), the Estimate or Actual

Beneficial Occupancy Date, and the Estimate or Actual Final Cost of the project. The last two entries were dependent on the phase of project.

The next section was designed to collect the history of the project's use of LEED and the actual or estimated LEED Certification Level. The section is lengthy, but set up chronologically for the Navy's planning and delivery process, as described above. First, a question is asked if a LEED Checklist has been completed for the project at any point in the process. The next item requested was the LEED credits estimated at the time the Activity Form 1391 was submitted to the Regional office. The data collected at the FACD phase included: Yes Credits, Possible Credits, and the Goal Certification level. At the next phase of delivery, the 100% Design stage, both the number of Credits, and the Goal Certification level were collected. At the completion of the project delivery, the Credits and Final Certification level, and whether the project was USGBC Registered, were entered. Next, it was asked if the design contract included any LEED Documentation. If so, the Final LEED Documentation Cost was collected.

For each project, Energy Savings in kilowatt-hours per year and dollars per year were collected. The project team was also asked to provide the Energy Cost Savings as a percent of the "baseline" building energy budget. Water Savings was collected as gallons per year and dollars saved per year. Additionally, the percent reduction of water use from the baseline building was collected. This section was developed for long-term use by the Navy's Sustainable Development Program. None of this data was used during the analysis portion of this research project.

Recording the Collected Data

The Navy's Sustainable Development Program Director, Dennis Talton, first introduced the data collection effort to the Sustainable Development Team members (one for each Region) via an e-mail (Appendix C). An individual follow-up e-mail was sent to each team member with a list of projects for his or her Region (Appendix D). Any questions the team members had during the process were answered promptly as they only had three weeks to collect the desired data.

Each Sustainable Team member returned their Regional template to the researcher via e-mail and the following actions were performed for all projects. The data template first was stored electronically in its original version. Next, it was reviewed for content and validity. If data templates were received with conflicting information, the researcher contacted the team member to have the data clarified. Each Regional template was then copied and pasted into a master template by the researcher. When the master template was completed, data columns were reviewed to ensure data similarity. If a team member submitted data that was not in the requested format, the researcher made slight changes to entries in order to have the data set the same, such as changing and entry from D-B-B to DBB. One other column was created after the data was collected. The project size entry was collected in either square meters or square feet. The researcher separated these values into two columns and made a simple calculation to convert one to the other such that both columns were completed. The final data template can be found in Appendix E.

RESULTS

Data Received

Data templates were received from six of nine (66%) Regional Sustainable Development Team members. A summary of the MCON projects for which data was received is provided below in Table 1.

Table 1. Summary of Projects

Description	Number of Projects
Total number of FY04-FY06 projects.	109
Deleted from research before sending data requests due to lack of applicability to LEED (Piers, wharfs, entry gates etc).	28
Projects sent out for data collection	81
Total projects in final template (includes additional projects submitted by Regions).	85
Projects not included in analysis because of project cancellation or lack of applicability to LEED (i.e. water treatment plant repairs).	12 (14%)
Projects not included in analysis because no data was provided.	23 (27%)
Possible projects to include in analysis.	50 (85-12-23=50) (59%)
Projects with more than one LEED score over the project horizon included in analysis.	25 (29%)

Twenty-eight projects were not included in the data collection because of their apparent lack of applicability with the LEED Sustainability rating system. These projects were primarily pier and wharf construction or repair, security upgrades to base entry gates, and runway or airfield construction. It was determined that useful sustainability data would not be available for these projects, and asking for data would frustrate and discourage the people asked to provide the data.

The remaining projects (81) were organized by Region and sent to the Sustainable Team members for data collection as described in the Methods section of this report. These projects were considered valid for data collection because the project scope was related to building construction or renovations. And thus, the LEED rating system was likely applicable to these projects.

After data was received on the 81 projects, four additional projects were included in the master template of projects to bring the total number of projects for which data was collected to 85.

Of these 85 projects, twelve projects were not included in the analysis. The data collected for these projects was determined to be insufficient or not available. The projects in this group were either cancelled and no data was available, or were found to be not applicable to LEED. One example is a project that was the repair of a wastewater treatment plant and the construction was limited to piping and other utilities.

Twenty-three projects were not analyzed because no data was provided for the projects. The projects likely have usable data available, however the team member was not able to supply the data to the researcher.

The total number of projects available less the previously deleted projects amounted to 50. These projects had various amounts of data provided. Each of these projects was initially analyzed for its ability to describe a relationship between contract delivery method and LEED score over the project horizon.

To indicate any relationship between delivery method and the LEED scores, more than one LEED score over the project horizon was needed. Twenty-five projects met this criterion and were included in the advanced analysis of this research. These 25 projects were divided by delivery method; there were 14 DB and 11 DBB projects.

Summary Statistics for Analyzed Projects

Table 2 presents the summary statistics for the 11 DBB projects analyzed. The table shows LEED scores at four points over the project horizon: FACD with "Maybe" credits, "Yes" only credits at FACD, credits at 100% Design, and credits at final completion. The first LEED score was calculated by adding the data collected for definite "Yes" credits and the "Maybe" credits from the FACD effort. The second time period included only the "Yes" points from the FACD. The next time period was the LEED score when the project design had reached 100%. And the last LEED score was when the project was completed.

Table 2. Summary Statistics for DBB LEED Scores (n=11)

	No. of Projects	Average LEED Score	Standard Deviation	Minimum	Maximum	Range
FACD with "Maybe" Credits	10	27.8	6.4	20	44	24
Yes Credits at FACD	10	25.3	4.6	15	30	15
Credits at 100% Design	10	27.8	6.7	16	36	20
Credits at Completion	7	23.7	4.9	16	30	14

There were 10 projects included at the first time period (FACD with "Maybe" Credits). The average (mean) of the LEED scores for these projects was 27.8 with a standard deviation of 6.4 (range= 20 to 44). Scores at the FACD (only "Yes" credits) for 10 projects averaged 25.3 with a standard deviation of 4.6. There were 10 projects included at the 100% Design complete time period. The average (mean) of the LEED scores for these projects was 27.8 with a standard deviation of 6.7. Only seven projects were available for analysis at the final completion stage. The average of the LEED scores for these projects was 23.7 with a standard deviation of 4.9.

The LEED scores at the FACD with "Maybe" credits included time period were excluded from the final analyses due to the probability that the teams for each project would likely approach "Maybe" credits in different ways. For example, one team may have approached maybe credits with less concern for the costs or challenges of implementing the credits later in the design process. On the other hand, another team may have been much more conservative on which "Maybe" credits were added to the scorecard because of the concerns for implementation challenges.

Figure 2 shows the scatterplot of LEED scores at each time period. Figure 3 demonstrates the relationship of the mean, median, and range using a Box and Whisker plot for this data. In Figure 3, the range is shown as the two lines extending from the sides of the box. The box represents the range of the inner 50% of scores. The vertical line in the box represents the median score and the "x" is the mean score. Any outliers are small squares outside of the above features.

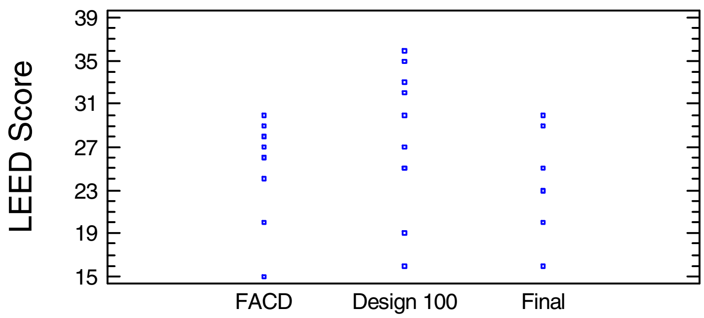

Figure 2. Scatterplot of LEED Scores over project horizon for DBB projects

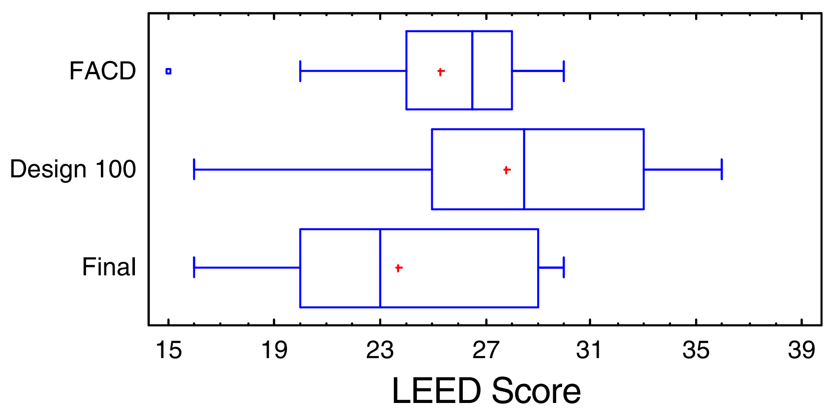

Figure 3. Box and Whisker Plot of LEED Scores over project horizon for DBB projects

Table 3 presents the summary statistics for the 14 DB projects analyzed. The table shows LEED scores at three points over the project horizon, FACD with “Maybe” credits (deleted from analysis for the same reason stated above), “Yes” only credits at FACD, and credits at 100% Design. There were no projects that had scores available at final completion.

Table 3. Summary Statistics for DB LEED Scores (n=14)

	No. of Projects	Average LEED Score	Standard Deviation	Minimum	Maximum	Range
FACD with "Maybe" Credits	14	29.8	8.7	16	42	26
Yes Credits at FACD	14	26.1	5.9	16	38	22
Credits at 100% Design	5	24.2	4.6	16	27	11
Credits at Completion	0					

There were 14 projects included at the first time period. The average (mean) of the LEED scores for FACD with "Maybe" Credits projects was 29.8 with a standard deviation of 8.7. Scores at the FACD (only "Yes" credits) for 14 projects had an average (mean) LEED score of 26.1 with a standard deviation of 5.9. There were only five projects included at the 100% Design complete time period. The average (mean) of the LEED scores for these projects was 24.2 with a standard deviation of 4.6.

Figure 4 shows the scatterplot of these scores at each time period. Figure 5 demonstrates the relationship of the mean, median, and range using a Box and Whisker plot for this data. Because there are only five projects with scores at the 100% design time period, a full Box and Whisker plot for these projects could not be constructed.

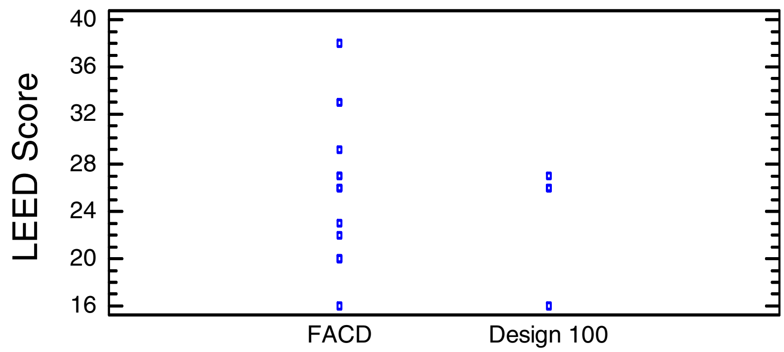

Figure 4. Scatterplot of LEED Scores over project horizon for DB projects

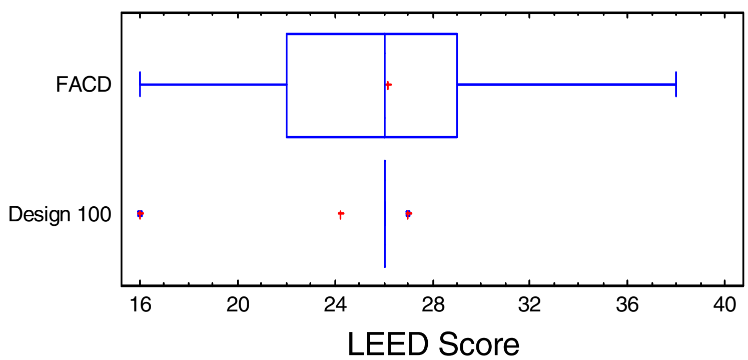

Figure 5. Box and Whisker Plot of LEED Scores over project horizon for DB projects

Difference in LEED Score between Delivery Methods

To determine if there was a relationship between delivery method and LEED score at any given time, a hypothesis test was performed. At the FACD phase, the null hypothesis was stated as follows: the mean of the LEED score for DB projects is equal to the LEED score for DBB projects. This hypothesis cannot be rejected at a 95% confidence level (*p*-value = 0.71). This can be seen graphically in Figure 6. The mean LEED scores are shown as the bars and the 95% confidence intervals are the lines extending vertically from the bars. The confidence intervals for each set of scores almost completely overlap. If there were a statistical difference in means, the intervals would not overlap. The same is true for the means at the 100% Design phase. The null hypothesis for the means being equal cannot be rejected at a 95% confidence level (p-value = 0.30). The smaller p-value indicated that the intervals do not overlap as completely as the FACD scores. The intervals and means can be seen in Figure 6.

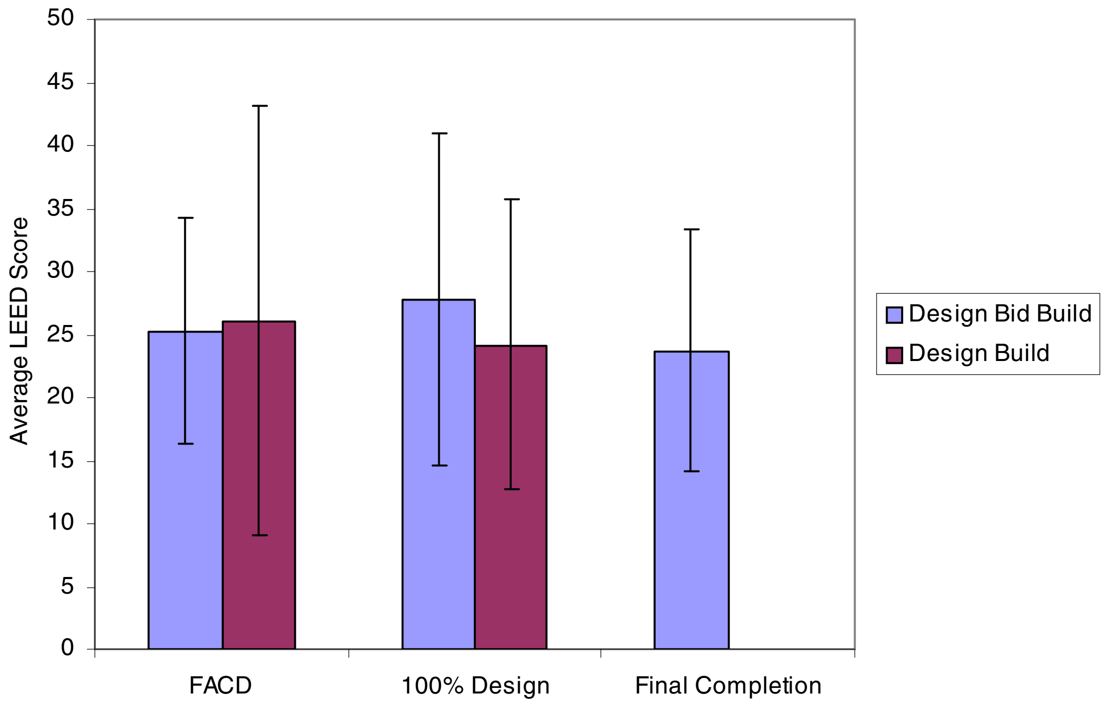

Figure 6. Comparison of Means and the 95% Confidence Intervals for FACD and 100% Design phases

Another result from Figure 6 was related to the rise or fall of LEED score over the project horizon. For the DBB projects the LEED score rises between FACD and 100% design and then drops at 100% design. This progression of LEED score over the project horizon may be a result of the constructor's expertise in not being introduced into the project until after the 100% design is completed. For DB projects the LEED score drops between FACD and 100% design. This result may demonstrate that the constructor's knowledge was introduced during the design phases. Although no completed DB projects were analyzed, it could be expected to seen the LEED score remain the same as 100% design or possible rise a small amount. Since only 25 projects analyzed, it would be difficult to make general conclusions from this result.

Difference in LEED Score across Time Periods

To determine if there was a statistical difference between the LEED scores across the time periods considered without involving the delivery method, a hypothesis test was used. Because there were no projects with LEED scores at the final completion phase for DB contracts, a hypothesis test was not used at this time period. Any results from this test would only be from DBB projects and could possibly alter the data interpretation. Considering this, the null hypothesis tested was stated as: the mean of the LEED scores during the FACD phase is equal to the mean of the LEED scores at 100% design. The null hypothesis cannot be rejected at a 95% confidence level (p-value = 0.63). Figure 7 shows the means and the 95% confidence intervals. Again, because the intervals overlap to a high degree, no statistical difference between the mean LEED scores at FACD and 100% design can be claimed. Figure 8 shows the scatterplot of the scores at both time periods.

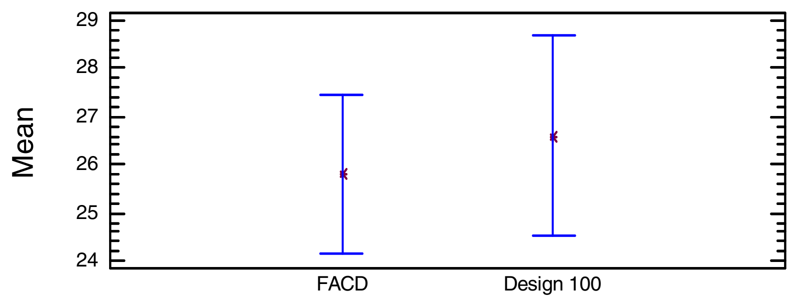

Figure 7. Means and 95% Confidence Intervals for FACD and 100% Design LEED Scores

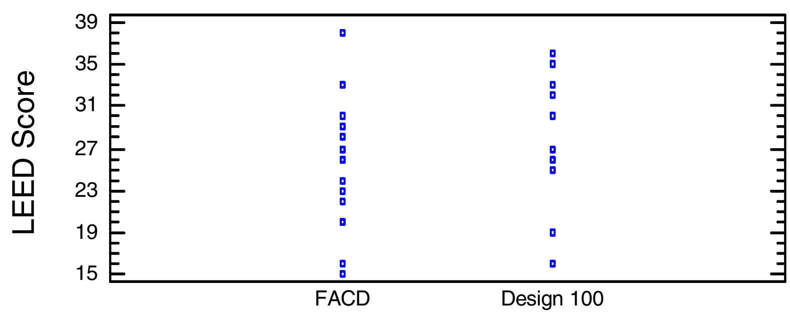

Figure 8. LEED Scores at FACD and 100% Design

Relationship between LEED Score and Project Cost and Size

Linear regression analyses were conducted to determine the relationships between LEED scores and total project cost, project size (square feet), and the normalized value of dollars per square feet. The analyses were performed at the 100% design time period with no separation by delivery method. However, the data points are labeled with their respective delivery method designation. Using project cost as the independent variable and project LEED score as the dependent variable, there was no significant relationship found. Figure 9 shows the scatterplot of LEED score at 100% design and project cost.

Using project size as the independent variable and project LEED score as the dependent variable there was no relationship confirmed. This can be seen in Figure 10, a scatterplot of LEED score at 100% design versus project size. Using project dollars per square foot as the independent variable and project LEED score as the dependent variable there was no relationship confirmed. This can be seen in Figure 11, a scatterplot of LEED score at 100% design versus project size.

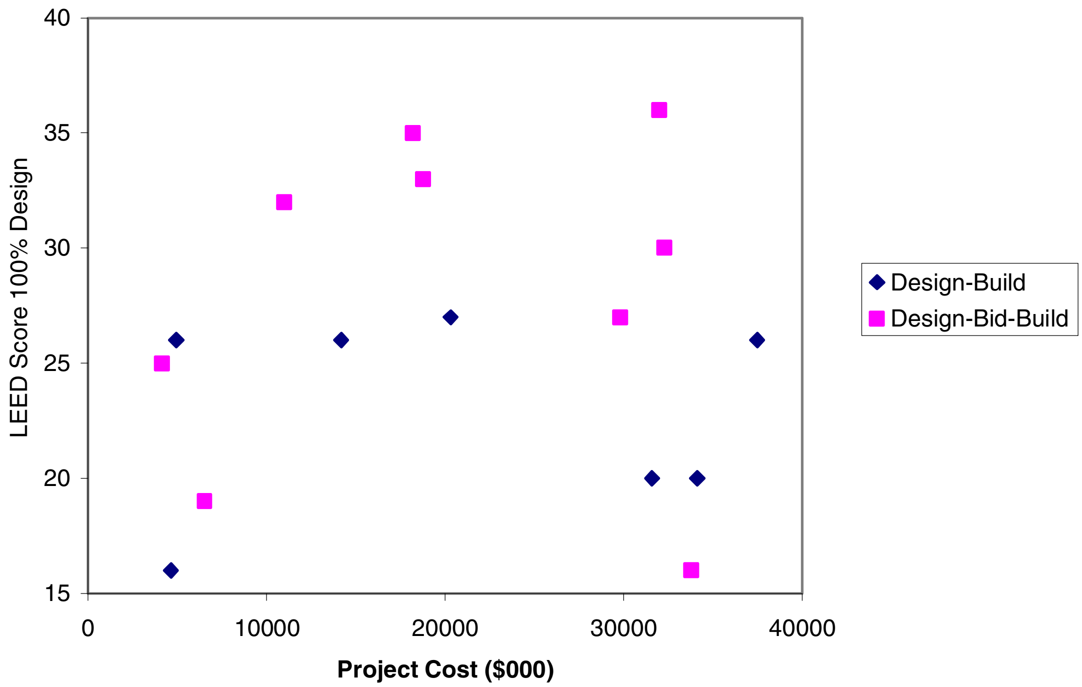

Figure 9. Scatterplot of Project LEED Score and Project Cost

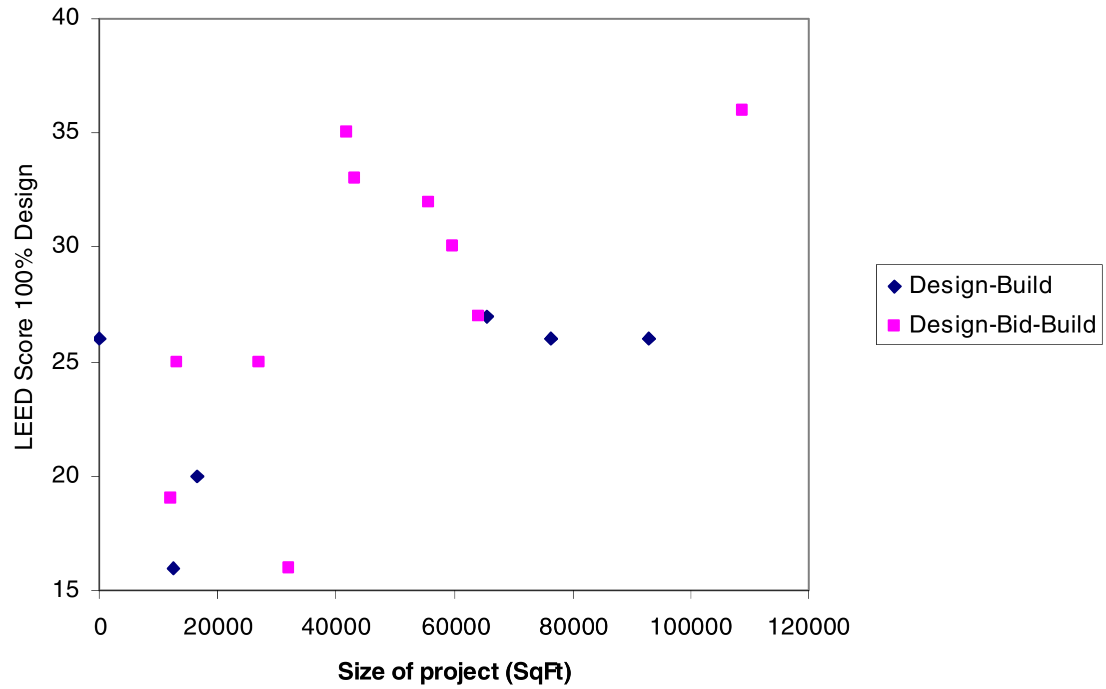

Figure 10. Scatterplot of Project LEED Score and Project Size

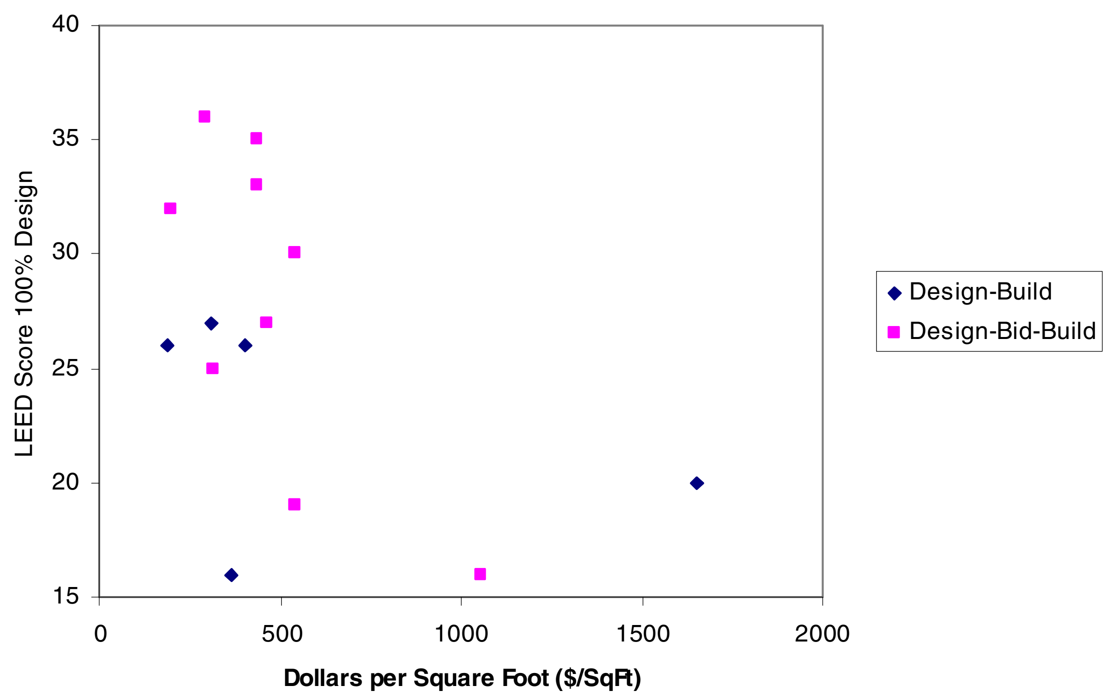

Figure 11. Scatterplot of Project LEED Score and Project Cost per Size

None of the regression analyses performed showed sufficient evidence ($R^2 = 0.004$ to 0.3) to say there was a relationship between LEED score and project cost or size. This result is expected due to the independence that LEED score has from either project cost or size. A project does not have to meet a minimum or maximum cost or size in order for it to reach a particular LEED score. The credits were intended by USGBC to be independent of either of these factors. One item of note is that for this research study, projects were all over the $750,000 threshold. The reader should consider that current Navy policy only requires LEED be used for projects over this dollar value when generalizing the results to projects valued at lower amounts.

Another interesting result from the regression scatterplots was seen in Figure 10. It was noticed that LEED scores for projects greater than 40,000 sqft were 26 or more. And similarly projects smaller than 40,000 sqft had LEED scores of 26 or fewer. With only 25 projects analyzed, it is difficult to make general conclusions from this result.

Assumptions and Limitations

Some simple assumptions were made with this research project. First, it was assumed that the people asked to provide data did so in a diligent and honest manner; therefore they gave the best information they had available. Next, it was assumed that none of the people involved in providing the data were aware of the research question and therefore could not alter data accordingly. And finally, it was assumed that the instructions for data collection were clear and fully understandable for all participants, enabling data similarity. Based on these assumptions, that data is judged to be valid and an accurate representation of the sample projects.

Another assumption made for this study was related to the similarity of the projects analyzed. The first filtering of projects for this research was to exclude projects that were primarily horizontal construction. This decision forced the remaining projects to be vertical construction and therefore applicable to the LEED New Construction scorecard. Although the normalizing quantity of dollars per square foot for the analyzed projects ranged from \$163/sf to \$1,650/sf, the fact that each project could be fairly measured using the LEED scorecard made them comparable for this study. Therefore, the 25 projects analyzed were fair representatives of the same population and statistical conclusions were valid.

There were some limitations to the data collection effort for this research project. Because of the short time available to collect the data (Summer 2005), there was not sufficient time to ask for additional data before analysis had to begin. Each fiscal year for the Navy ends in September. In the summer months, the NAVFAC facilities team must be focused on executing expiring funds, not gathering data for a research project. Additionally, Hurricane Katrina that affected much of the Gulf coast impacted that Region's data collection efforts. Additionally, members of NAVFAC from all over the country were sent there to support recovery, which may have limited the extent to which other Regions gathered data.

CONCLUSIONS

There are three significant findings from the research study. First, no noteworthy difference was found between DB and DBB in terms of LEED scores at the FACD and 100% design time periods. Second, considering all 25 projects, there was no significant difference in the LEED scores between the FACD and 100% design time periods. And finally, there was no evidence that a relationship exists between either total project cost or project size and the LEED scores. While these findings provide a picture of the projects analyzed, more data could have made the results more substantial and generalizable to all applicable Navy MCON projects.

A total of 73 projects could have been analyzed had all of the Regional team members submitted their data on time. In addition, of the 50 projects that had partial data, only 25 had LEED scores in more than one time period. One reason for the missing data could be that about a third of the total projects were not fully in the design phase or the design was just beginning and therefore the 100% design LEED score could not be gathered.

Dividing the 25 projects by delivery method yielded 14 DB and 11 DBB. Because of a lack of data from the DB projects at the Final Completion time period, no comparison between methods was performed. Also, because of the possible inconsistency of considering the impacts for any 'maybe' LEED credits across the entire group of projects, none of the data from the FACD scores that included 'maybe' credits was used. That left the FACD scores and the 100% design scores for comparison. Neither of these time periods resulted in significantly different mean LEED scores between delivery methods. This result could or could not be representative of the entire 73 possible projects. Without additional data, no conclusion could be reached. The result that there is not a significant difference could be considered a positive result for the Navy. It means that although more analysis should be performed, the delivery methods are not negatively or positively impacting the LEED scores over the design horizon. This may be related to the fact that the designers of both delivery methods have similar interaction with the Navy. It is typically the owner's responsibility to make certain the design meets the project goals and objectives; and in this case, the Navy is responsible for ensuring that the projects complete the design phase with the highest level of sustainability, independent of delivery method.

LEED scores were analyzed across time periods without differentiating for delivery method. Again only the FACD and 100% design time periods were examined. There was no evidence to suggest that the mean LEED scores for the two time periods are different. Again, this result could or could not be accurate across the entire 73 possible projects; however without additional data, no conclusion could be reached.

In a final effort to explain any relationships of the LEED scores and other project data, linear regression analyses were performed. When three simple linear regressions were conducted for 100 % design LEED scores and total project cost, project size (square feet), and dollars per square foot, no relationships were confirmed with any confidence. Because LEED score is independent of either project cost or size, this result is expected.

The LEED rating system is designed in such a way that a project does not have to meet cost or size requirement in order to earn a particular LEED score. With this result, one can conclude that LEED scores are not affected by either project size or project cost.

Review of the 25 projects analyzed showed that only two of the seven completed projects had reached the LEED Certified level of 26 or more credits. There were another eight projects poised to earn the Certified level as they had 26 or more points at the 100% design phase. Only one project at the 100% design phase, with a LEED score of 16, would not reach LEED Certified level. The score for this project had not changed over the entire design process.

RECOMMENDATIONS

The U.S. Navy would benefit from continued efforts in researching sustainable development implementation. Most importantly, annual data, using the template developed for this research, must be collected and analyzed. It is also recommended that the results of this research be confirmed using additional data, especially related to differences in LEED scores on projects using the two delivery methods of Design-build and Design-bid-build. Another area for continued research in the possible result that LEED score is somehow related to project size. Lastly, another area for more research is to use the energy and water savings data collected from the template to justify any additional costs that a project might incur to provide sustainable features.

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APPENDICES