3-22-2012

Reducing Operating Costs by Optimizing Space in Facilities

Jared J. Maline

REDUCING OEPRATING COSTS BY OPTIMIZING SPACE EFFICIENCY IN FACILITIES

THESIS

Jared J Maline, Capt, USAF

AFIT/GEM/ENV/12-M14

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GEM/ENV/12-M14

REDUCING OEPRATING COSTS BY OPTIMIZING SPACE EFFICIENCY IN FACILITIES

THESIS

Presented to the Faculty

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Engineering Management

Jared J. Maline, BA

Captain, USAF

March 2012

AFIT/GEM/ENV/12-M14

REDUCING OEPRATING COSTS BY OPTIMIZING SPACE EFFICIENCY IN FACILITIES

Jared J. Maline, BA
Captain, USAF

Approved:

/SIGNED/	24 Feb 12
Lt Col Peter Feng, Ph. D., P.E. (Chairman)	Date
/SIGNED/	6 Mar 12
Lt Col William E. Sitzabee, Ph. D., P.E. (Member)	Date
/SIGNED	15 Feb 12
Lyne Hunter, AFDW A7/CA (Member)	Date

AFIT/GEM/ENV/12-M14

Abstract

The purpose of this research was to determine which factors are important to space optimization in office buildings. The next step was developing an analysis and grading scale for current and proposed utilization rates for the government's inventory. Facility and maintenance costs represent a large portion of the government's expenditures and need to be reduced to meet energy efficiency goals as well as ensuring fiscal responsibility from the government. The government has no all encompassing optimization standards or means of integrating these requirements into a decision making model.

This research culminates in the development of a metric to evaluate spatial efficiency in current facilities and set standards for futures buildings. The potential savings are highlighted using Air Force Real Property inventory as a case study. The metric is designed as an asset management tool that can assist decision makers on where to spend their limited resources to maximize their return on investment.

Acknowledgments

I would like to thank my committee members for their assistance in developing this thesis. I would like to express my sincere appreciation to my committee chairman, Lt Col Peter Feng, for his guidance and support throughout the course of this thesis effort even while deployed.

Jared J. Maline

Table of Contents

List of Figures

List of Tables

REDUCING OEPRATING COSTS BY OPTIMIZING SPACE EFFICIENCY IN FACILITIES

I. Introduction

Background

Space optimization has become a key component when it comes to cost control for both sustainment and utility funds. The introduction explains why space management must be addressed, the potential savings, and what questions this paper has attempted to answer to resolve this problem.

There are a number of drivers behind the current push for fiscal responsibility within the government. The current economic recession and reduced tax revenue is only a small part of the current drive towards a leaner and more efficient spending policy. Like any smart business the Air Force (AF) should continually evaluate expenditures and costs to streamline its budget to promote reinvestment, and also free up funds for other programs.

Added to this are mandated requirements listed in the AF Infrastructure Energy Plan (2010) to promote leadership in energy efficiency as well as reducing expenditures to deal with a reduced budget. All of these drivers are meant to reduce the 2008 energy costs of $6.4B by the Air Force (SAF/IE, 2010). $1.1B of this is dedicated to facility energy with the remainder going towards fuel (SAF/IE, 2010).

Air Force Civil Engineers are responsible for maintaining 160,000 assets and 10M acres worth roughly $263B (HQAF, 2010). Air Force assets house roughly 450,000 active duty and civilian employees. The United States Government employs almost 2.8M civilian personnel (US Census Bureau, 2009) while the DOD employs roughly 3M (US Department of Defense, n.d.). With such a large asset portfolio, a reduction of 1-2% of overall facility costs could have tangible financial benefits.

Major external drivers to reduce these costs started in 2005 with the Department of Energy's (DoE) Energy Policy Act of 2005 which created a 40% more stringent energy standard than the existing standard in the Code of Federal Regulations (CFR). President Bush's Executive Order 13423 entitled "Strengthening Federal Environmental, Energy, and Transportation Management," followed shortly thereafter. In response to these drivers the updated Air Force Energy Policy was published in 2007 to set basic guidelines on how the Air Force should begin going about achieving these goals at the strategic level. The previous Air Force Civil Engineer, Major General Del Eulberg, came up with the 20/20 by 2020 vision as an effort to assist Civil Engineers (CE) with a tactical level perspective on how to deal with the 60% budget cuts (Culver, 2007). The objective was to achieve a 20% reduction in physical infrastructure and 20% reduction in energy consumption by 2020.

Unfortunately there is little to no guidance at the Operational level on how each base should achieve these energy, maintenance, and construction cost savings. This leads us to the problem statement of this thesis and a key component of how we could achieve these reductions.

Problem Statement

Currently there are no Federal or DOD standards for building efficiency, also known as building utilization rates, housing the business of 5.8M government and DOD employees. We continue to spend money on maintaining or increasing our footprint when we have no idea of current utilization. A method must be developed to quantify this factor along with the toolset necessary for asset managers and base leadership to make educated decisions on where and how to spend limited resources. The following problems will be addressed:

1. Is there a space utilization standard that could be implemented to better control spiraling costs for space and energy?
2. What reductions in quantity or cost savings could be achieved through the implementation of such standards?
3. What would be the components of a quality space management program?
4. Can the program, standards and metrics be executed in a way that doesn’t create an undue burden on the Asset Management Flight and other organizations within Civil Engineering?

Research Objectives/Focus

The goal of the research was to attempt to answer the problem statements listed above. This was done by determining what constitutes a facility with a low/medium/high utilization rate. Also, what components or attributes create synergy in attaining space optimization? Current best practices used by private business and their adaptability for use by the government have been evaluated. Standards for current and future facilities have been developed for implementation. These standards, and evaluation of current usage, allow potential savings to be calculated. Once that was established a toolset has been developed to help facilitate decisions at the operational level.

The most fruitful location for this information is from data published by businesses, organizations, and schools with similar types and use of space. Other governments, colleges, and large multi-facility businesses face similar real property management issues and were the ideal starting point for data discovery. Additionally, there are multiple organizations that research these topics and publish papers, journal articles, and books on the subject. This information helped to develop a list of primary components that achieve an effective space management program.

Throughout the process applicability and workload burden generated by the new standards and tools were considered. A cost benefit analysis was conducted for the proposed solution to ensure no organization or employee receives a burdensome workload as a result of these recommendations.

Assumptions/Limitations

The Automated Civil Engineering System (ACES) and base S-files provided the data for analysis. ACES is the program that CE units utilize to store past, ongoing, and future project information such as scope, cost, and other pertinent data. The S-file is a standalone database at each base that stores property management information such as number of personnel, net and gross square footage, and current usage. The Pacific Air Force (PACAF) command utilizes a similar software program that was developed prior to the S-file but the software is not part of the analysis in this thesis. Facility data for PACAF facilities was made available for inclusion into the analysis by Air Force Headquarters staff.

The information retrieved will only be good as the data that has been entered into each database. Not all facilities were reviewed to determine if the data had been maintained and updated as necessary due to time and labor constraints. Base level engineering units will provide facility floor plans, furniture layouts, and staffing documentation as necessary.

One obstacle involved ensuring equivalent data were evaluated from alternative sources. There is no single measurement and definition of standards for evaluating facilities and their building efficiency ratios. In fact the American Institute of Architects (AIA) measuring standards first line states that there is no single measurement standard for area of buildings (AIA, 2007). Because of this a single standard was selected for this paper. The GSA has recently adopted the Building Owner's and Manager's Association (BOMA) standards for measurement so these will similarly be adopted for the purposes of this research (GSA, 2006). The assumption is that future government decisions will be based upon BOMA standards and the content of this thesis will remain relevant with no need to alter calculations or space data.

Implications

The implications of this research involve a fundamental shift in thinking for decision makers at the strategic and tactical levels. Often it is deemed easier to build new or seek out a new space for an emerging requirement. Instead we should better utilize what we have and remove excess, inefficient, or substandard physical inventory to more efficiently house millions of federal employees. A 2-3% reduction in square feet could have major financial savings seen across new construction, maintenance, and utility budgets based upon reduced utility, service contract and life cycle costs. Using consistent and replicable standards for space use could have annually compounded savings each year as maintenance and utility reductions are maintained, new facilities meeting the higher standards replace older facilities, and additional facilities are renovated.

II. Scholarly Article

Prepared for Submittal to the ASCE Family of Publications

Reducing Operating Costs by Optimizing Space Efficiency in Facilities

Jared J Maline, Peter Feng, Lyne Hunter and William E. Sitzabee

Abstract

Facility maintenance and sustainment costs can represent a large portion of a company's expenditures. The government has a pressing need to reduce these costs and meet energy efficiency goals while remaining fiscally responsible. Research has shown the government currently has little to no optimization standards or means of integrating these requirements into a decision making model. This is despite the fact that the data necessary to make educated decisions are already being collected through asset management and geospatial activities.

This paper utilizes the Air Force's facility portfolio as a case study to better understand the problems and potential solutions of space optimization for large organizations or governments. The culmination of this research was the development of standards to evaluate spatial efficiency in current facilities while mandating standards for futures buildings. It’s designed to be utilized as an asset management tool that assists decision makers on deciding where to spend limited resources to maximize their return on investment.

Introduction

The need for space optimization is best understood after evaluating the current costs of ownership for real property assets, utilities, and land owned by the government. Like any smart business the Air Force must continually evaluate these costs to streamline its budget in order to promote reinvestment and free up funds for other programs. The U.S. government and Department of Defense (DOD) are also working to promote leadership in energy efficiency while simultaneously dealing with a reduced budget. All of these drivers are meant to reduce the 2008 energy costs of $6.4B by the Air Force (SAF/IE, 2010). $1.1B of this is dedicated to facility energy as shown in Figure 1 (SAF/IE, 2010).

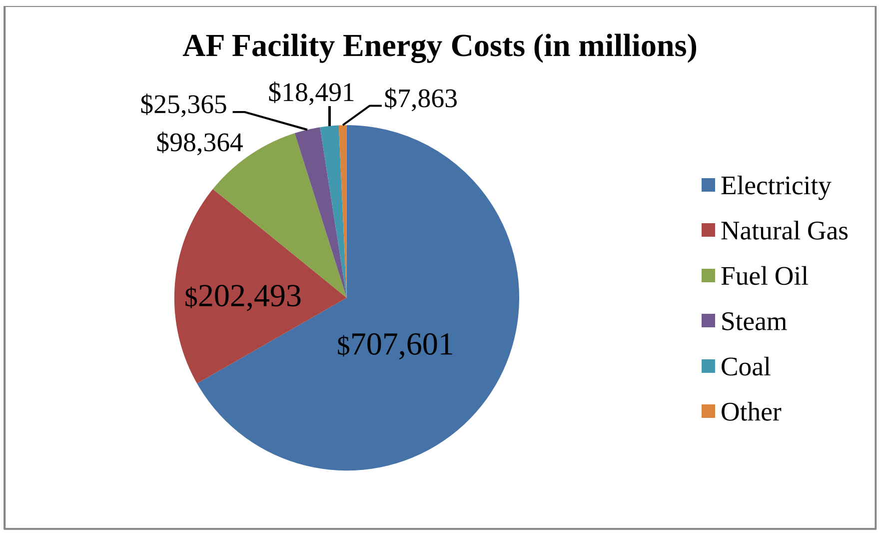


Figure 1: Annual Facility Energy Costs by Type

Air Force Civil Engineers are responsible for maintaining 160,000 assets and 10M acres worth roughly $263B (HQAF, 2010). Air Force facilities house roughly 450,000 active duty and civilian employees. The United States Government employs almost 2.8M civilian personnel (US Census Bureau, 2009) and the DOD employs 3M (US Department of Defense, n.d.). With such a large asset portfolio, a reduction of 1-2% of overall facility costs could have tangible financial benefits.

Major external drivers to reduce these costs started in 2005 with the Department of Energy's (DoE) Energy Policy Act of 2005 which created a 40% more stringent energy standard than the existing standard in the Code of Federal Regulations (CFR). President Bush's Executive Order 13423 entitled "Strengthening Federal Environmental, Energy, and Transportation Management," followed shortly thereafter. In response to these drivers the updated Air Force Energy Policy was published in 2007 to set basic guidelines on how the Air Force should address these goals at the strategic level. The previous Air Force Civil Engineer, Major General Del Eulberg, came up with the 20/20 by 2020 vision as an effort to assist Civil Engineers (CE) with a tactical level perspective on how to deal with the 60% budget cuts (Culver, 2007). The objective was to achieve a 20% reduction in physical infrastructure and 20% reduction in energy consumption by 2020.

Unfortunately there is little to no guidance at the Operational level on how each base should achieve these energy, maintenance, and construction cost savings. The purpose of this paper is to address these shortfalls by developing standards and a decision making model.

Research Objectives

A method must be developed to determine spatially efficient factors, quantify them for analysis, and develop the toolset necessary for asset managers and base leadership to make educated decisions on where to spend limited resources. The following problems are addressed:

1. Is there a space utilization standard that could be implemented to better control spiraling costs for space and energy?
2. What reductions in quantity or cost savings could be achieved through the implementation of such standards?
3. What would be the components of a quality space management program?
4. Can the program, standards and metrics be executed in a way that doesn't create an undue burden on the Asset Management Flight and other organizations within Civil Engineering?

Assumptions/Limitations

The Automated Civil Engineering System (ACES) and base S-files provided the data for analysis. ACES is the program that CE units utilize to store past, ongoing, and future project information such as scope, cost, and other pertinent data. The S-file is a standalone database at each base that stores property management information such as number of personnel, net and gross square footage, and current usage.

The information retrieved will only be good as the data that was entered into each database. Data wasn't confirmed with facility inspections due to the quantity and diverse locations. Base level engineering units provided facility floor plans, furniture layouts, and staffing documentation as necessary.

One obstacle involved ensuring equivalent data was received from alternative sources. There is no single measurement and definition of standards for evaluating facilities and their building efficiency ratios. In fact the American Institute of Architects (AIA) measuring standards first line states that there is no single measurement standard for area of buildings (AIA, 2007). Because of this a single standard from the Building Owner's and Manager's Association (BOMA) for measuring office space was used.

Background

A review of pertinent literature consisted of analyzing books, journals, articles, and company/government documentation and standards. The information gleaned from these sources fell into the following primary categories:

1. The Cost of Space
2. Building Efficiency Ratio
3. The Open Floor Plan
4. Average Net Square Footage Per Person
5. Components of a Space Management Program

The cost of space highlights the importance of proper space management. It lays out the costs associated with each worker as well as costs related to sustainment per square foot. Items two through four present information on three components that were found to be critical to managing space. They analyze gross square footage, net square footage, and flexibility of the space. The final area reflects best practices and other criteria deemed critical to effectively manage space. The five categories are expanded upon, and their importance explained, below.

The Cost of Space

The first step in analyzing this problem is by understanding current costs to house federal employees and how the government compares without outside organizations. It helps answer Question 2 of the problem statement by understanding what costs factor into real property and where potential savings may lie. Additionally, Question 3 of the problem statement will gain initial information by understanding what components factor into costs and therefore what components a space optimization program must address in order to be effective.

The savings potential of space optimization can be highlighted after evaluating the cost per employee. The Art of Space Management (Steiner, 2005) evaluates office space costs and size by geographic region. North American companies have one of the highest costs of over $6,000 per person as well as the largest average office space sizes. Costs ranged from under $4,000 in the Middle East to over $8,000 in Western Europe.

The substantial costs faced by the government is broken out in the 2006 U.S. General Services Administration (GSA) Real Property Performance Results. The estimated cost of a dedicated work station was $15,200 per person of which $8,300 is for information technology (IT) and $6,900 for facility and utility costs. The $6,900 is a more important figure compared to Steiner's North American results because the government doesn't pay for its real estate in most instances (HQAF, 2010). The government received most of its land through grants or eminent domain and doesn't pay property taxes on the land or facilities. Despite this fact, there has been a steady increase in these costs since 1998 when it was $11,000. Over that same timeframe 100K additional employees have been added to the government and given work stations (GSA, 2006).

The exclusion of land ownership costs is best shown by another measure in the GSA report . The GSA performance data (2006) shows the average cost per square foot was $4.86 for government owned space while leased space cost $21.25 per square foot. These numbers have remained steady, with a slight upward trend, since 1996 when the data collection first began. Businesses view land as an asset that can be bought or sold while the governments property is a static asset not viewed as something that builds value or can be bought or sold for profit. The more than four times higher price for leased facilities reflects the appraised value of the assets as well as overhead and profit for the organization providing the service.

Despite the footprint and costs of ownership the government and DOD currently have no standards for an office buildings efficiency ratio. The only guidance provided by the AF is Air Force Handbook 32-1084 which lists cubicle size for certain jobs and ranks. This is a microscopic view of a much larger system that has yet to be fully addressed. To begin to solve this problem we must evaluate the current system for allocating space, develop realistic goals on how to alter the system, execute the changes, and monitor the progress.

The Space Management Group was contracted to develop special standards for the UK's higher education system (Chiddick, 2006). Their conclusion was that a spatially efficient design must consider the following:

1. Ensure space efficiency is a conscious target for each project
2. Collect and use data related to space, cost and use for strategic decision making
3. Incorporate appropriate design specifications and ideas
4. Carefully specify and plan furniture purchases and placement
5. Follow a quality systematic process in all decisions

The per person costs can be better understood with a real world example that highlights the price difference based upon different office sizes in two facilities with different efficiency ratios. Table 1 shows two facilities, one with a 70 percent building efficiency ratio and the second with a 50 percent building efficiency ratio. Using the available office space and an estimated sustainment cost of $4.80 per square foot we determined both the number of potential personnel housed for each office size and the annual cost per person for each configuration (GSA, 2006). Table 1 illustrates how factors such as building efficiency ratio, net square feet per person, and the office layout impact the overall costs associated with space. It does so by comparing two similarly sized facilities built around different space standards for building efficiency, net square feet per person and office size. To keep the scenario simple it is assumed that all workstations consist of one type: pod, cubicle or enclosed office for each of the two facilities. Since each facility is 10,000 gross square feet the sustainment costs are equal for both (10,000*$4.80=$48,000). Net square feet per person metrics are calculated by dividing the number of personnel housed by the total office and support space for each facility. The cost per person is determined by the number of personnel housed divided by the sustainment cost of $48,000 annually.

Facility 1 has a more ideal building efficiency ratio of 70% and can house between 80 and 40 personnel depending on if pods, cubicles, or closed offices are selected. Facility 2 has a less ideal 50% building efficiency ratio and can house between 53 and 26 personnel. When you compare the most efficient scenario in facility 1 (80 personnel at $625 per person) to the least efficient scenario in facility 2 (26 personnel at $1923) per person it quickly becomes apparent that space utilization can have a significant impact on a company's cost and footprint.

Table 1: Density and Cost Analysis of Two Facilities

Facility 1:
70% Bldg efficiency ratio
Gross Sq Ft: 10,000
Office Space: 6,000 sq ft
Support Space: 1,000 sq ft
Sustainment cost @$4.80/sq ft: $48,000

	Pods	Cubicles	Closed Office
Workspace Size	75 sq ft	100 sq ft	150 sq ft
# of people housed	80	60	40
Net Sq Ft/person	87.5	116.6	175
Cost per person	$625	$833	$1250

Facility 2:
50% Bldg Efficiency Ratio
Gross Sq Ft: 10,000
Office Space: 4,000 sq ft
Support Space: 1,000 sq ft
Sustainment cost @$4.80/sq ft: $48,000

	Pods	Cubicles	Closed Office
Workspace Size	75 sq ft	100 sq ft	150 sq ft
# of people housed	53	40	26
Net Sq Ft/person	94.3	125	192.3
Cost per person	$943	$1250	$1923

Building Efficiency Ratio

The ratio of net square footage to gross square footage is critical when it comes to the initial cost of construction as well as the life cycle costs of a facility. Architectural programming books state that the initial size of the facility is the biggest driver when it comes to utility consumption and maintenance costs in future years (Pena, 2001) (Kumlin, 1995). Whether or not a person is occupying a space it costs the same to light and condition it. So any reduction in space has the biggest effect on utility and maintenance savings. Why retrofit a light with a 10% more efficient unit when you have the opportunity to remove it altogether and save 100% of the energy through space optimization?

The alternative viewpoint is that a lower building efficiency ratio can be considered good for an established business as it shows prosperity and excess wealth (McGregor, 2000). Many established companies were built with larger offices, entryways, and add other purely aesthetic treatments purely to portray the image of success even though it costs more to operate in the long run. However, a military installation isn't the appropriate location for such a statement to be made nor is it necessary.

Some organizations have taken the desire to impress outsiders and created slightly lower efficiency standards for headquarters or leadership buildings. Some examples include the University of New Mexico and the Georgia Government, however, they both maintain higher standards for all other facilities to ensure cost control remains a top priority (Space Management Office, 2007) (Office of Planning and Budget, 2001).

Table 2 reflects a collection of building efficiency ratios deemed appropriate by architects and planners of facility programming guidelines, universities, and state governments. They range from 65-82% for office space with an average of 70%.

Table 2: Sampling of Office Efficiency Ratios

Organization	**Efficiency Ratio**	**Notes**
AIA reference guide	65%	
State of Georgia	55-77%	Typical office bldg
	53-71%	Headquarters office bldg
University of New Mexico	82%	Typical office bldg
	74%	Leadership office Bldg
The Architects Portable Handbook, Pat Guthrie	70%	
Space Management Group	80%	Net leasable
University of Utah	70%	
Problem Seeking, William Pena	67%	Deemed most economical

The Open Floor Plan

There is no such thing as a single layout that is most efficient for every use (Becker, 1995). Since a facility typically remains in the military's inventory for its usable life it should be designed to be flexible and easily adaptable to current and future missions. Adjacency, distance, and other factors should be considered to optimize the layout of a floor plan for a new organization (Meller, 1996). Additionally, AFI 32-1032 paragraph 2.2.1.1 mandates that we design facilities to meet the mission while also ensuring the flexibility to accommodate future changes with minimal cost.

Unfortunately there are no prescribed methods or recommendations for ensuring the flexibility of a workspace and it’s left up to the programmer and project manager to develop these requirements for each project. If the initial sizing and requirements for a facility are most critical in determining the overall life cycle costs, the programming of those standards shouldn’t be left to individual experience and training in an organization that experiences high turnover rates.

Most current research reviewed below involving the use of an open floor plan hinged around worker productivity, communication and employee satisfaction. There is no consensus on whether the open floor plan or enclosed office layout is best, or what attributes are improved the most with either system. Below are some examples that examine both sides of the issue.

Franklin Becker (2001) conducted research that showed a tangible increase in worker productivity when placed in an open floor plan that facilitated interaction. It was considered important in organizations that involve communication, interaction, brainstorming, and creativity. The level of communication and number of interactions greatly increased over that of enclosed offices. This is despite the fact that person’s perceptions in a survey showed that individuals in hard offices felt they were communicating as much as people in cubes. Personnel in hard offices often interacted only during formal meetings and not during day-to-day tasks. Productivity, communication, and learning were increased (Becker, 2001).

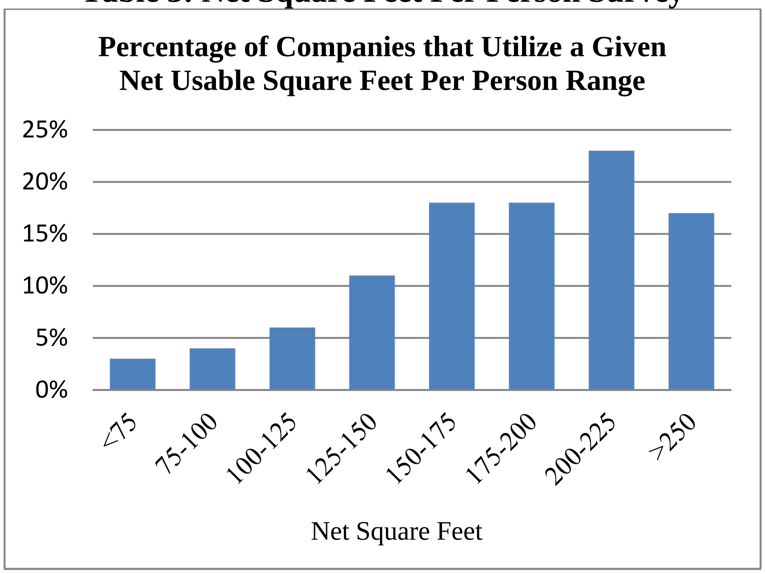
A yearlong study was conducted that looked into an alternative work strategy where no one had their own office, but worked at communal tables and employees could sit wherever they wanted (Allen, 1973). Job satisfaction as well as communication increased significantly with the new arrangement. There was no tangible increase in job performance noted.

Although the above sources differ on whether an increase in job performance occurs; none of the sources listed a reduction in job performance. Although even authors who strongly supported open floor plans such as Becker (2001) and Dess et al. (1999) cautioned against utilizing all open offices. The benefits of the open plan must be weighed against the needs of managers, personal privacy, and avoiding the alienation of senior workers who feel entitled to their own office.

Net Square Feet Per Person

Another strong metric for overall special efficiency is net square feet per employee. This measurement takes the total net square footage and divides it by the number of employees assigned to that space. The GSA has recently adopted a standard of 200 net square feet per person (GSA, 1997). The GSA also notes that there is no incentive for organizations to reduce space. The Air Force recently adopted the same 200 square feet per person standard but other information should be analyzed to determine what is occurring in the private sector (Byers, 2010). A large survey conducted by Steelcase evaluated 194 corporate real estate practitioners looked at space standard used by private industry (Steelcase, 2009). 92 percent of organizations that participated in the survey had over 1,000 employees while 62 percent had over 10,000. The size of these organizations is important as the average number of personnel at Air Force installations is 3,529 (DMA SECAF, 2011). The survey is a meta analysis of what similarly sized organizations have done to address space concerns as well as they standards they've utilized. The result of the survey are shown in Table 3 below.

Table 3: Net Square Feet Per Person Survey



The survey shows that 60% of large organizations are functioning in a spatial standard that is less than 200 square feet per person. Some organizations, such as the Department of Agriculture's Forestry Service, operate on much stricter standards (USDA, 2006). Any office over 20K Gross Square Feet (GSF) can't exceed 200 GSF per person. Office's below 20K GSF can't exceed 230 GSF per person. This measure is achieved in part by very strict standards for individual offices, support spaces, and the use of alternative work strategies. State level forestry managers are unable to get an office larger than 200 square feet. Additionally all part time employees, and workers who spend 60% of their time away from their desk, are required to share a workspace. Bathroom size, number of showers, custodial space, and mechanical rooms are also strictly regulated based upon overall facility size and number of employees. This shows a significant reduction in private industry space allocation compared to the GSA survey results that averaged 200 net square feet per person (GSA, 1997). It also shows many organizations working in situations well under 200 square feet per person. Some organizations considered it to be liberal and excessive resulting in their much lower space standards (Steelcase, 2009).

The level of detail found in the Forestry Service is in stark contrast to the Canadian Government. Public Works and Government Services Canada publishes an architect's guide for sustainable facilities (Cole, 1999). Within the document there is no mention of space use, spatial metrics, or other standards to ensure an efficient facility. Another Canadian Government publication is The Environmentally Green Office at a Glance (PWGS, 2000) which contains checklists of considerations that should be reviewed during the planning of a new office or renovation. The mission statement of the Green Office Plan is to "further sound environmental policy in an economically efficient way". There is no mention of spatial efficiency. Instead it focuses on energy use, water consumption and indoor air quality. As mentioned previously, the fact that overall office size is the largest contributor to energy use is ignored in spite of its intended focus on utility conservation.

The only document the Canadian Government has made available to the public that mentions space is the Fit-up Standards (McBain, 2009). It states that offices can be no less than 100 square feet and can be as large as 300 square feet. Shared spaces such as meeting rooms are afforded a large range of flexibility and even allow for coat closets for visitors. This document makes the same mistake as the Air Force's AFH 32-1084 which is focusing on individual components and ignoring the big picture. Although individual spaces are managed the larger system is ignored. Both focus more on ensuring those of a certain rank get a specific size office versus an overarching concern for total space management and the costs associated with the policy.

Components of a Space Management Program

To understand what components should make up a space management program, one must understand the roadblocks to the execution of a space optimization program. Some of these issues include lack of vision, leadership turnover rates, U.S. Air Force culture, and lack of incentivization.

Current Air Force energy policy is focused on component acquisition or replacement, but it lacks the big picture view of what needs to be addressed. The focus on aggregate components versus addressing interactions in a holistic approach is a root cause of waste in business processes (Womack, 2003). Why should we swap out fixtures for more efficient ones when we can improve the system as a whole and completely remove the facility resulting in far greater gains?

Leadership turnover can also impact long term organizational objectives. A solid space optimization program requires a long term strategy and focus to be effective (Chiddick, 2006). Some successful organizations consider long term goals far more important than short term financial goals (Liker, 2004). Additionally, congressional mandates limit the military's ability to leverage large up-front costs for long term savings. Minor construction limits of $750K, and MAJCOM imposed limits of $700K to prevent project failure, severely limit the ability of leadership to leverage expenditures and risk.

Congressional mandates also prevent the military from moving money across organizational boundaries to seek out the most optimal solution.

Another issue facing acceptance and integration of space standards is current military and governmental cultural views on the decision making process. The concept is one of presiding over a process versus taking ownership of the problem and the development of a solution (Gerstner, 2002). Until base leadership makes some of these goals their own then no tangible benefit will ever be realized. This problem then ties into leadership turnover as leadership may decide space is important but will quickly move to a different assignment.

The final roadblock to success presented is the lack of incentivization for leaders to reduce space. In an organization that has no sales, no profits, and no discernible product, leadership doesn't view costs as a priority. So cost cutting initiatives with no perceived benefit to each individual leader take a low priority against other goals. This is also tied to growing leaders that understand the philosophy, live by it, and teach it to others (Liker, 2004).

In an effort to incentivize leaders the standards within this paper should be integrated into the project prioritization system. This would require leaders to understand the standards, consider them, and make space optimization a priority or else risk never getting any of their facility initiatives approved by having them moving lower on the prioritization list. Leaders that excel at following efficiency standards are rewarded with a higher proportion of projects being prioritized high enough to get executed each year.

The Big Picture

To better understand one of the goals of this research; a discussion of a larger model will be discussed. The three components previously discussed will be entered into a larger equation being developed by other researchers in the areas of energy efficiency, mission rating, and facility condition. The end result will be a project and facility scaling system that encompasses critical areas of concern and assist senior leadership in making funds allocation decisions. A primary goal of the formula is to develop quantifiable criteria that reduce the ability of individuals to game the system. The end result is an enhanced decision making tool based upon tangible and explainable criteria. Figure 2 shows the new formula; the three highlighted parts are covered in this paper and focus on space optimization.

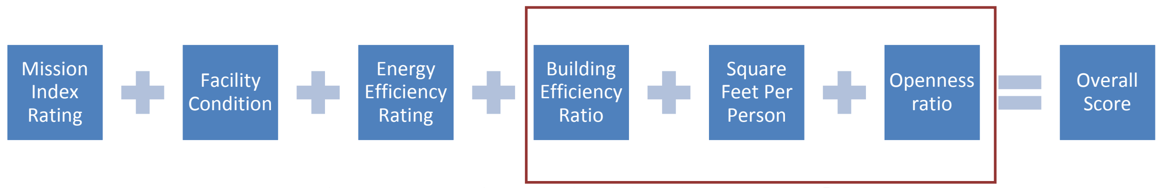


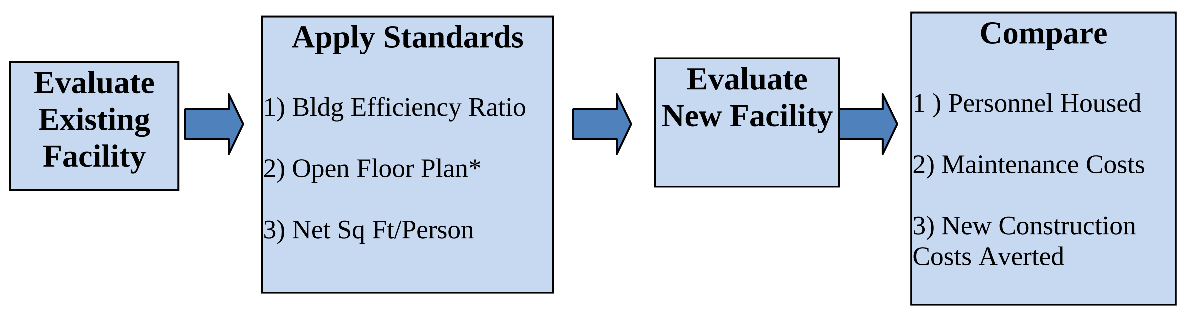
Figure 2 Project Prioritization Formula

The primary difference between the new formula and existing is that it considers energy consumption and space use as a means of raising or lowering the priority of a project. This would cause funds to be spent on projects that improve space or energy use before projects that don’t. Although this paper focused on the three space components of the equation further research will be conducted to evaluate the overall model.

Methodology

The three primary components to be tested are building efficiency ratio, net square feet per person and an open floor plan. These three components have had standards generated based upon the previously discussed research. They were then applied to 1,496 Air Force facilities categorized as administrative by category code within Real Property records. The new floor plans were evaluated compared to its original condition. It was evaluated for number of personnel housed, maintenance and utility savings, as well as new construction costs averted if the additional office space needed to be constructed. The analysis model is presented below in Figure 3.

Figure 3: Model for Testing of Standards



*Applied to individual floor plans to test the 80/20 ratio. Time constraints and availability of floor plans prevented the editing of all 1,496 floor plans. Five were evaluated for trend analysis.

feet. Their size ranged from 816 to 640,067 square feet and had a standard deviation of 37,855. Currently 1.7M square feet is vacant which represents 5.5% of the total available space. Based upon the Office of the Deputy Under Secretary of Defense's *Base Structure Report* (2010) the total square footage to be analyzed represents (30,300,000/619,100,000=4.89) 4.9% of the total Air Force inventory.

The Standards

1) Building Efficiency Ratio. The average building efficiency ratio of .70 was utilized for analysis of office buildings. A building efficiency ratio of .65 was used on headquarters facilities. This allowed for a balance of cost efficiency as

well the desires of Wing leadership to have a more open facility for hosting Air Force leadership, distinguished visitors, and community leaders.

2) Open Floor Plan. The literature review of open floor plans discussed the benefits and drawbacks of an open floor plan. No sources were found that discussed a proportion of open to closed offices intended for financial and sustainability targets. This research project evaluated an 80% open floor plan. The number was created based upon the following assumptions and analysis. The 80/20 ratio will provide hard offices for Commanders, senior enlisted and officer leaders, flight chiefs, or others personnel a Squadron Commander determines to require one. The standard is intentionally designed to not provide a hard office for every non-commissioned officer, non-commissioned officer in charge, and officer in an organization. The ratio was developed based upon the need to counsel, administer punishment, not alienate senior employees, and allow for senior leaders to have privacy. The flexibility of an open floor plan allows for additional enclosed offices through the use of systems furniture if it is required and meets the intent of AFI 32-1032 which stipulates that office space be flexible and meet the needs of the end user with minimal renovation costs.

3) Net Square Feet Per Person. Although BOMA and the Air Force adopted a standard of 200 net square feet per person the survey data shows many organizations are working under far stricter standards. Floor plans were measured to determine the current situation as well as reevaluated after the space optimization criteria were applied to see if a stricter standard is feasible.

Results/Analysis

This section will discuss the results of the three standards, analyze the results, and provide recommendations based upon the results and analysis.

Building Efficiency Ratio

Once the standards were applied summary data were collected to determine what, if any, benefit could be realized. The current mean is 0.68 with a standard deviation of .1 for the 1,496 facilities analyzed. Applying a building efficiency ratio of .65 for office buildings and .7 for headquarters facilities reduced total real property from 30.3M gross square feet to 25.37M for a total change of 4.93M square feet. This is a reduction of 16.3% in gross square footage. Total sustainment dollars could have been reduced by ($4.80*4,931,062SF=$23,669,098) $23.7M and new construction costs of ($172.83*4,931,062SF=$852,235,445) $852.2M would have been averted if this standard was followed.

Net Square Feet per Person

The median for 1,496 facilities is 216 square feet per person with a range of 21 to 2,979. The median was required to be used to describe the data set due to the skewness. Skewness is a measure of asymmetry of the probability distribution of a real valued random variable (Weinberg, 2008). A positive number reflects a tail to the right while a negative number reflects a tail to the left. The level of skewness was measured using the following formula (Weinberg, 2008):

$$\text{Skewness} = \frac{N}{(N-1)(N-2)} \frac{\sum(x_i\text{-x-bar})^3}{(SD)^3} \qquad (1)$$

where N is sample size, x-bar is the mean, and SD is the standard deviation. The skewness for this data set is 4.43 reflecting a long tail to the right.

To measure variability in a heavily skewed data set the interquartile range (IQR) is more appropriate than standard deviation (Weinberg, 2008). The IQR measures statistical dispersion by determining the boundaries and spread of the middle 50 percent of the data (Weinberg, 2008). IQR is calculated using the following formula:

$$IQR=Q_3-Q_1 \tag{2}$$

where IQR is interquartile range, Q_3 is the third quartile, and Q_1 is the first quartile. The data had an IQR of 143 and ranged from 161 to 304 net square feet per person.

Kurtosis was measured to evaluate the peakedness of the distribution. Kurtosis is a descriptive statistic designed to show the peakedness or heaviness of tails based upon the fourth moment about the mean (Berkman, 2012). A high kurtosis distribution has a sharper peak and longer, fatter tails, while a low kurtosis distribution has a more rounded peak and shorter, thinner tails (Berkman, 2012). Kurtosis is measured with the following formula:

$$\text{Kurtosis}=\sum\frac{(xi\text{-}x\text{-}bar)}{SD}4 - \frac{3(n-1)^2}{(n-2)(n-3)} \tag{3}$$

where x-bar is the mean, SD is standard deviation, and n is the number of data points. The kurtosis was 25.4. The data set is described as leptokurtic which has an acute peak and fatter tails (Berkman, 2012).

The heavily skewed and leptokurtic data set shows there are certain buildings that are far worse than others in a non-normal distribution. The long tail highlights the fact that there are numerous facilities well above the desired standards within the AF inventory. Analysis of the outliers showed many of the worst offenders to be small facilities under 10,000 square feet with one or two personnel. These facilities should be addressed first through renovation to house additional employees or else demolished and the personnel consolidated into other facilities.

Currently 16.95M square feet are utilized for office space. Application of the 200 net sq ft per person would reduce this number to 13.1M sq ft, or a reduction of (1-(13,848,668/16,951,816)=18.3%) 18.3%. Utilizing a stricter standard of 180 net sq ft per person would result in a reduction of (1-(13,139,173/16,951,816)=22.5%) 22.5% or 13.1M square feet. The reduction in sustainment costs for 200 and 180 square foot per person standards would be ($4.80*3,103,148=14,895,110) $14.9M or ($4.80*3,812,643=18,300,686) $18.3M respectively. Averted construction for the 200 and 180 square foot per person standards would have been ($172.83*3,103,148=536,317,069) $563M or ($172.83*3,812,643=658,939,090) $659M respectively.

Open Floor Plan

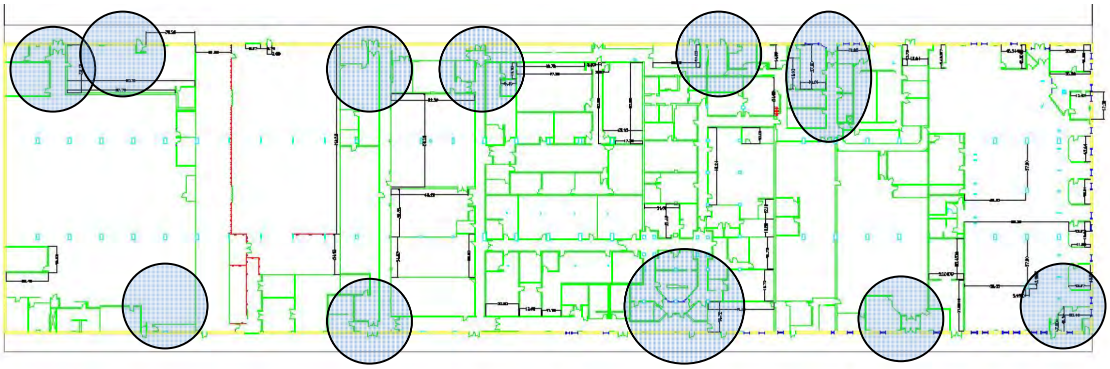
The open floor plan was tested on five floor plans while keeping the other two metrics in mind. Significant benefits were noted above and beyond the 200 net square foot per person metric. Even in facilities that were already spatially efficient such as building number 34006 a benefit was noted. Additionally, the 180 sq ft/person was a good maximum however much more efficient designs are possible in certain floor plan layouts. Any attempt to use the standard as a target should be avoided; it should be used as a cap. Table 4 shows the five analyzed facilities and the personnel housed, net square feet per person, and percent difference of the two items before and after application of the standards. An average increase of 54% in the number of personnel housing in each facility was noted. Additionally, there was a reduction in net square feet per person of 29%. The data reflects that the standards can easily be met or exceeded in existing facilities.

Table 4: Before and After Application of Standards

Bldg #	Personnel Before	Personnel After	% Diff	Net Sq Ft/Person Before	Net Sq Ft/Person After	% Diff
10280	334	615	+84%	233	165	-31%
20011	87	147	+69%	300	179	-40%
20047	22	40	+82%	194	107	-45%
34006	159	164	+3%	105	101	-4%
34012	191	248	+30%	134	103	-23%
Average	**158.6**	**242**	**+54%**	**193**	**131**	**-29%**

There were some items of note when analyzing a floor plan. Figure 4 shows the before and after floor plans of building 10280. Over time more and more divisions were created within the facility. This led to redundant entrances, primary circulation space, and lobbies. The evolving changes led to a reduction in the building's efficiency ratio and created large areas of wasted space. By consolidating the number of internal office areas with an open floor plan the amount of wasted space was reduced with no major structural changes to the facility. The end result was an improvement of 84% in the number of personnel housed and an improvement from 233 to 165 net square feet per person. Figure four highlights the number of entrances and lobby areas before and after the floor plan alterations. The number of entrances and lobbies was reduced from eleven to six resulting in significant space savings.

Before



After

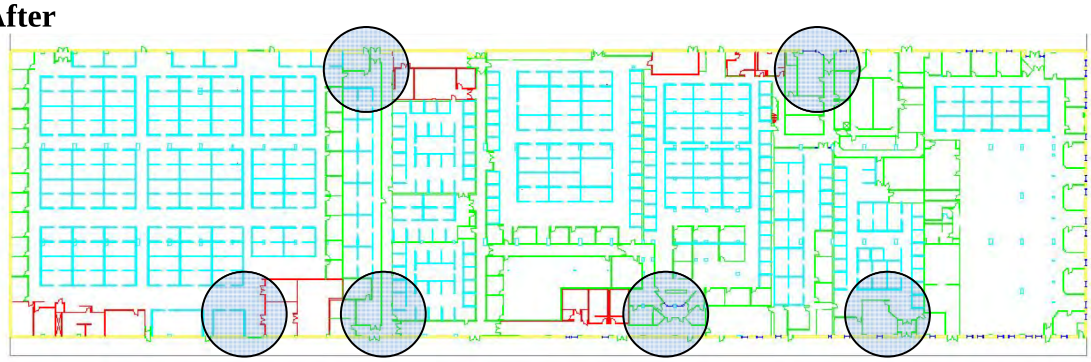


Figure 4: Floor Plans and Entrances for Bldg 10280

Analysis

While conducting research on existing facility inventory the smallest facilities, those under 10k square feet, were deemed the least efficient. Many of the worst performing buildings were one to three thousand square feet with only one or two employees. This resulted in net square feet per person metrics ranging from 500-2300 square feet per person. The facilities were either underutilized, poorly designed or had dual functions but were still coded as administrative.

There were some small facilities that were deemed efficient by meeting the 200 net square feet per person metric but still had inefficient layouts when analyzed. One example was building 20047 which housed 22 employees with 194 net square feet per person. Figure 5 below shows there was a large amount of wasted space due to redundant entry areas, lobbies, and primary circulation space. The small facility doesn't need three primary entrances with their own lobbies but they were added over time. The end result is an inefficient building and highlights the fact that the 200 net square foot per person metric is a poor indicator of spatial health on its own due to the fact that it ignores gross square footage.

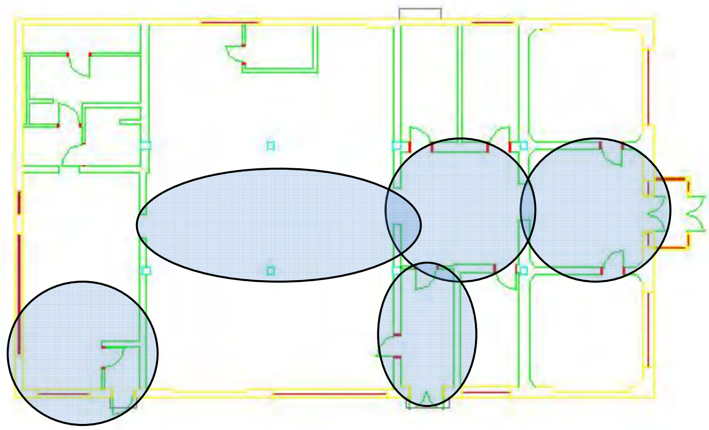


Figure 5: Building 20047

Minor construction limitations prevents construction costs from exceeding $750K. Additionally many MAJCOM's refuse to approve projects that exceed $700K due to the risk of exceeding the spending cap and causing project cancelation. The Ohio area is facing construction costs for administrative facilities of $172.83 per square foot (Balboni, 2011). At the current cost of construction these limitations would get you a new facility of ($700,000/172.83=4,050) 4,050 square feet. These house the least number of personnel in an inefficient manner but still require all of the utilities, component maintenance, and service contracts that larger facilities require.

There were some areas where the standards didn't work as well without impacting the function of the facility. They were primarily dual use facilities that were coded as administrative as well as headquarters facilities. Headquarters buildings had a large concentration of office spaces that were over 200 square feet in size. Attempting to provide both the offices, meeting areas, and support space wasn't possible in facilities that functioned purely as headquarters buildings. Larger facilities with multiple floors and diverse functions to include headquarters responsibilities may be able to achieve the standards once averaged over the total square footage.

One of the most interesting facts was noted in facilities with multiple Squadrons or functions collocated in the same facility. Each organization had hard walls between them despite similar administrative work types. This created a divisive and inflexible work space that removed the possibility for low cost and flexible expansion capabilities of both parties. Facility 34012 was 90% administrative and contained 26 hard walled divisions. Each area involved similar administrative work in regards to noise levels, type of work, etc. A large amount of floor space had to be devoted to circulation space to deal with the divisive floor plan. Removing some of the unnecessary divisions led to a large increase in floor space as shown in Figure 6 below. A 30% increase in the number of personnel housed in the facility was attained. The number of hard walled divisions was reduced from 26 to 15.

Before **After**

Figure 6: Before and After Divisions Within Building 34012

Additionally, although only one floor of a facility may house a headquarters function the entire facility was classified as a headquarters. Changes should be made to the classification system to assist in space optimization on a within-facility scale. Additionally, only 30.3M of the 58.4M administrative square footage is classified as administrative within Air Force real property records (SECDEF, 2010).

Actual office sizes versus authorized were available for one base. A number of issues arose in reviewing the data. Actual space exceed authorized by 25%, or 196K square feet. Additionally, there were inconsistencies in the number of higher level personnel listed versus actual. This shows that current labeling systems are inadequate or require clear justification of what positions fall into each category. Complete data of the Air Force position standard versus actual observed data for Wright Patterson Air Force Base is shown in Table 5 below.

Table 5: Position Space Standard Versus Actual

Job Function	Number of Personnel	Observed Office Area (SF)	Authorized Standard (SF)	Total (Number * Observed)	Total (Number* Authorized)
Wing Commander	40	303	350	12,120	14,000
Deputy Wing Commander	33	270	350	8,910	11,550
Group Commander	49	233	250	11,417	12,250
Deputy Group Commander	15	190	250	2,850	3,750
Squadron Commander	80	249	200	19,920	16,000
Deputy Squadron Commander	26	231	150	6,006	3,900
Flight Commander	92	183	150	16,836	13,800
First Sergeant	11	132	120	1,452	1,320
Superintendent	65	197	120	12,805	7,800
NCOIC	591	162	120	95,742	70,920
Secretary	55	225	120	12,375	6,600
Worker/Administrative	5,800	127	100	736,600	580,000
Student	1	29	25	29	25
IMA	2	129	100	258	200
Contractor	307	99	100	30,393	30,700
Civilian Volunteer	4	117	60	468	240
Total SF				**968,795**	**773,055**

One other concern noted in the application of the standards is that it may actually be too efficient at adding bodies and require additional bathrooms or electrical capacity to be added to meet the new demand. In the case of building 10280 the almost doubling of personnel, from 334 to 615, may highlight limitations of utility systems. The cost of upgrading transformers, water lines, or waste lines may make the cost of the project infeasible so this must be taken into consideration during the planning phase. However, the organization may deem the investment worthwhile as a number of facilities could be demolished if the additional capacity of 281 personnel were consolidated from other facilities.

The total projected savings in sustainment expenditures could total ($23,669,098+14,895,110=38,564,208) $38.5M or ($23,669,098+18,300,686= 41,969,784) $42M annually depending on which standard is followed. The total averted construction costs could total ($852,235,445+536,317,069= 1,388,552,514) $1.4B or ($852,235,445+658,939,090= 1,511,174,535) $1.51B based upon the standard followed. These savings were achieved by applying the standards to only 4.9% of the total Air Force inventory and yet removed ((4.93M+3.81M)/619.1M*100=1.4%) 1.4% of the total 619.1M in square footage.

Recommendations

The items listed below are recommendations for a solid space optimization program that can lead to improved results. Merely having standards isn't enough

1) Create leaders that own the standards and make decisions with space and energy goals in mind. Having an expert within CE isn't enough.
2) Systematically collect and update space information. Quality decisions can't be made if the data in ACES RP and the S-aren't accurate.
3) Measure the baseline, agree on space targets, monitor their attainment and report to senior management. This is the fundamental flaw with the current system that is addressed by this paper. Space targets must be developed, monitored, and have a readily understandable metric made available to senior leadership.
4) Collect standardized utilization data including office space utilization. Use of BOMA measurement standards will ensure all parties are using the same

guidelines. Information will be tracked within the S-File such as net square feet per person, occupants, net square feet, gross square feet, etc.

5) Collect and apply detailed cost information. Ensuring data is entered accurately is critical to understand which facilities should be evaluated for demolition or consolidation. Until the S-File can talk to other systems and pull the data this analysis must be accomplished manually.
6) Incorporate space efficiency standards into the real property strategy. The formula developed will incorporate these standards into the decision making model. Further research is necessary to evaluate its effectiveness.
7) Incorporate requirements for space efficiency into project programming and design reviews.
8) Promote the benefits of versatile spaces to reduce long term costs. The open floor plan metrics will allow for versatile spaces. Future research is needed to evaluate cost savings.
9) Include space efficiency information in post-occupancy evaluations. After facilities are renovated or built there should be a follow-up process to verify if the space is being used as intended and efficiently. This is similar to post-occupancy follow-ups for LEED certifications.

Conclusions

The research presented showed a significant benefit to the analyzed facilities. 28% of the square footage could be demolished for significant savings in both sustainment costs and new construction. By analyzing a small portion of the Air Force overall inventory (4.9%) a reduction of 1.4% was achieved. Further use of space standards in other category codes within the Air Force Real Property inventory could result in significant savings.

References

Allen, Thomas. (1973). A Field Experiment to Improve Communications in a Product Engineering Department: The Nonterritorial Office. The Journal of Human Factors and Ergonomics Society. Vol 5, No 5, pp. 487-498.

American Institute of Architects. (2007). AIA Document D101. AIA Press. New York.

Balboni, Barbara. (2011). *RS Means Square Foot Costs*. RS Means. Norwell, Massachusetts.

Becker, Franklin. (2001). Offices that Work: Balancing Communication, Flexibility, and Cost. Cornell University.

Becker, Franklin. (1995). Workplace by Design: *Mapping the High Performance Workscape*. Jossey-Bass. San Francisco.

Berkman, Elliot. (2012). A Conceptual Guide to Statistics using SPSS. Sage Publications. California.

Byers, Timothy A. (2010). S-File: Key to 20/20 by 2020 Success. *Air Force Civil Engineer*. 18(3), 5-10.

Chiddick, David. (2006). UK Higher Education Space Management Project: Promoting Space Efficiency in Building Design. Space Management Group. March, 2006.

Cole, R. (1999). Architect's Guide for Sustainable Design of Office Buildings. Public Works and Government Services Canada. British Columbia.

Culver, Michael. (2007). Transforming the CE Enterprise. *Air Force Civil Engineer*. 15(5), 4-12.

Defense Media Activity for the Secretary of the Air Force. (2011). Airman: The Book. AFD-110301-069. Retrieved on 5/31/11 from http://www.af.mil/shared/media/document/AFD-110301-069.pdf

Deputy Chief of Staff, Logistics, Installations and Mission Support (AF/A4/7). Air Force Infrastructure Energy Plan 2010. Washington: GPO, 2010).

Deputy of the Under Secretary of Defense. Base Structure Report Fiscal Year 2010 Baseline. Washington: GPO, 2010.

Dess, G. et al. (1999). Beyond Productivity: How Leading Companies Achieve Performance by Leveraging their Human Capital. American Management Association. New York.

General Services Administration. (2006). Real Property Performance Results 2006. Washington DC. GSA Office of Government-wide Policy.

General Services Administration. (1997). Office Space Use Review. Washington DC. GSA Office of Government-wide Policy.

Gerstner, Louis. (2003). *Who Says Elephants Can't Dance?* Harper Collins. New York.

Headquarters Air Force A7C. (2010). 2010 Almanac. *Air Force Civil Engineer*. 18 (4), 8-12.

Kumlin, Robert. (1995). *Architectural Programming: Creative Techniques for Design Professionals*. McGraw Hill. New York.

Liker, Jeffrey. (2004). *The Toyota Way: 14 Management Principles From the World's Greatest Manufacturer*. McGraw Hill. Wisconsin.

McBain, John. (2009). Fit-up Standards: Technical Reference Manual. Public Works and Government Services Canada. British Columbia.

McGregor, Wes. (2000). Facilities Management and the Business of Space. Butterworth-Heinemann. Burlington, MA.

Meller, R.D. (1996). Facility Layout Objective Functions and Robust Layouts. International Journal of Production Research. Vol 34, Vol 10. pp. 2727-2742.

Office of Planning and Budget. (2001). Guidelines for Predesign of Major Capital Projects. Georgia State Financing and Investing Commission. Retrieved on 1/18/11 from http://opb.georgia.gov/vgn/images/portal/cit_1210/14/28/162041300 predesign_guidelines_april_2001.pdf.

Pena, William. (2001). *Problem Seeking: An Architectural Programming Primer*. Wiley and Sons. New York.

Public Works and Government Services Canada. (2000). The Environmentally Responsible Green Office at a Glance. Public Works and Government Services Canada. British Columbia.

Space Management Office. (2007). Building Efficiency Ratio Guidelines. University of New Mexico. Retrieved on 3/11/11 from http://iss.unm.edu/PCD/SM/doc/

Building%20Efficiency%20Ratio%20Guidelines.pdf.

Steelcase. (2009). Space Standards Among Large Corporations. Steelcase. Michigan.

Steiner, Jon. (2005). The Art of Space Management: Planning Flexible Workspaces for People. *Journal of Facilities Management*. Vol 4, No. 1, 6-22.

United States Census Bureau. (2009). Federal Government Civilian Employment. Washington DC: US Government Printing Office.

United States Department of Agriculture. (2006). Space Planning Policy Service First Collocation and BLM OR/WA Space Policy. United States Department of the Interior, Bureau of Land Management. Retrieved 1/9/11 from http://www.fs.fed.us/servicefirst/docs/collocation-space-planning-policy.pdf

United States Department of Defense. (n.d.) DOD 101: An Introductory Overview of the Department of Defense. Retrieved 2/24/11 from the DOD website: http://www.defense.gov/pubs/dod101/dod101.html

Weinberg, Sharon. (2008). Statistics Using SPSS: An Integrative Approach. Cambridge University Press. New York.

Womack, James and Jones, Daniel. (2003). *Lean Thinking.* Free Press. New York.

III. Conclusion

Chapter Overview

This chapter discusses the research findings in relation to the questions outlined in Chapter 1. This chapter will review the findings in regards to the problem statements and whether or not they were fully answered. The significance of the research will then be discussed followed by recommendations for future research.

Review of Findings

In this section each of the problem statements from chapter 1 will be reviewed within the context of the findings.

1. Is there a space utilization standard that could be implemented to better control spiraling costs for space and energy?

Three standards were found to have a significant impact to space utilization. One key point is that a single standard was not enough to make a significant difference. Each of the three standards addressed a unique attribute to the space optimization standard. The building efficiency ratio addressed excess gross square footage that had no value added to the mission being conducted within the facility. The net square feet per person standard addressed the efficiency of the net square footage where employees worked. The open floor plan standard created work areas that were flexible for long term use and minimized future renovation costs for facilities that could remain in the Air Force inventory for decades or even centuries.

2. What reductions in quantity or cost savings could be achieved through the implementation of such standards?

When analyzing the 30.3M gross square feet a significant savings was evident. An annual reduction of $42M in sustainment costs could be realized. The total averted construction costs could total $1.51B if we had followed the standards or freeze future construction until current utilization is maximized. These savings were achieved by applying the standards to only 4.9% of the total Air Force inventory and yet removed 1.4% of the Air Force's gross square footage.

3. What would be the components of a quality space management program?

The recommendations section addressed the primary components of a space management program. The overarching theme present in all of the literature was that having a standard alone isn't enough. The standards must be integrated into the decision making of a company and become a focus for leadership. Education of the costs of space and need for change must become more prevalent while fostering leaders that make the goals of space optimization their own. Currently space use is a Civil Engineering Squadron problem but the entire Department of Defense is feeling the repercussions of the cost of space.

4. Can the program, standards and metrics be executed in a way that doesn’t create an undue burden on the Asset Management Flight and other organizations within Civil Engineering?

It was very important to develop standards and a decision making model that was feasible for use. All of the metrics used in the thesis are currently being tracked by Asset Management in the S-File. Implementation of the decision making model would simply alter the existing prioritization formula that Programmer's use to rack and stack projects.

In doing so it would educate both Civil Engineering leadership as well as outside organizations on space management.

One concern brought up with modular furniture is the lack of privacy or noise control. These concerns can be mitigated through proper design and careful selection of materials. Noise can be managed through diminishing the source, transmission control or altering the receiver. In the case of vocal noise, transmission should be addressed as source and receiver controls aren't feasible. Private enclosed offices can be built using systems furniture. Careful attention should be placed on ensuring doors aren't undercut with a gap of more than one half inch. A threshold should then be used to seal the gap. Non ceiling height walls are also a significant source of noise transmission that can be addressed. Place fiberglass insulation on top of ceiling tiles spanning four feet on each side of the wall or utilize a noise control membrane connecting the curtain wall to the ceiling. Additionally, ceiling tiles can be specified with a higher Ceiling Attenuation Class (CAC) and Noise Reduction Coefficient (NRC). These prevent transmission of sound as well as absorb greater amounts of noise.

Wall design can also be altered to improve the Sound Transmission Class (STC). This is an improvement in how well the wall system reduces noise transmission between adjacent spaces. By placing fiberglass insulation and using a noise isolating channel on one side to hang the gypsum board the STC can be increased from 33 to 52 which is a significant change for minimal additional cost (Egan, 1988).

Significance of the Research

The research is significant in that there is still a lot of progress to be made to achieve the 20/20 by 2020 goals. A common fear is that the low hanging fruit in regards to demolition and utility reductions have already been accomplished. I would argue that we've been looking in the same places we always have; aggregate components versus creating a holistic approach to space management. The next step in reductions must look at the big picture which is what this thesis did. Removing over 8M square feet from only 5% of the total inventory would go a long way towards meeting the larger goals. It also highlights the potential savings if we analyze the other 95% in the same fashion.

Future Research

The following items were noted as potential future research:

1) Open floor plan standards for headquarters buildings. Although the building efficiency ratio and square feet per person standards were able to be met the 80/20 open floor ratio was too high to house all the high level personnel.

2) Potential cost savings of open floor plans versus traditional floor plans

3) Implementation of the newly developed prioritization formula for new construction or renovation projects

4) An attempt to execute the standards in an actual facility.

5) Energy use monitoring comparison between a number of spatially inefficient facilities and one large consolidated facility housing an equal number of personnel with similar energy and environmental requirements.

6) Analysis and reduction of communication costs associated with providing a work station to a worker.

Appendix A

Building Efficiency Ratio: the ratio of existing net-to-gross area in a facility

Ceiling Attenuation Class (CAC): A measure for rating the performance of a ceiling system as a barrier to airborne sound transmission through a common plenum between adjacent closed spaces such as offices. A ceiling system with a CAC < 25 is consider low performance, whereas one with CAC > 35 is high performance.

Cost Per Square Foot Owned:

1) Cleaning: Includes labor costs for in-house and contract service, payroll, taxes and fringe benefits, plus salaried supervisors and managers, as well as expenses related to routine equipment and supplies required for daytime and nighttime cleaning of offices, elevators, public areas, rest rooms and windows. Also includes the costs of specialized cleaning services such as trash removal, recycling, window washing and carpet cleaning plus the costs of roads and grounds keeping services.
2) Maintenance: Includes all expenses required for general repairs, maintenance and upkeep of the facility. Labor costs include payroll, taxes and fringe benefits for employees and contracted workers. Personnel include operating engineers, general maintenance personnel and chief building engineers. Repairs and maintenance items include elevators; heating, ventilation and air conditioning; electrical; structural/roof; plumbing; and fire and life safety systems as well as maintenance supplies.
3) Utilities: Includes the cost of all utilities (electricity, gas, oil, purchased steam and hot water) used by the facility and its occupants.

Density: A metric for office space utilization measured in square feet per person. The measure of square footage is usually Usable Square Feet, but is occasionally Rentable Square Feet.

Gross Leasable Area: The floor area that can be used by Tenants. Generally measured from the center of joint partitions to outside wall surfaces.

Gross Square feet: The total area occupied by a building when measured from exterior to exterior. This area included all mechanical areas, walls, and vertical penetrations.

Net Leasable Area: In a building or project, floor space that may be rented to tenants; area upon which rental payments are based. It excludes common areas and space devoted to the heating, cooling, and other equipment of a building.

Net Square feet: The sum of all areas on all floors of a building either assigned to, or available for assignment to, an occupant or specific use, or necessary for the general operation of a building.

Leasable Area per person: The leasable area divided by the number of employees in the facility

Noise Reduction Coefficient (NRC): A measure for rating the overall sound absorption performance of a material when used in an enclosed architectural space such as an office, where sound is being reflected at many angles of incidence. Specifically, it is the 4 frequency averaged absorption coefficients @ 250, 500, 1000 and 2000 Hz, rounded to the nearest 0.05. A material with NRC < 0.50 is a poor absorber, and NRC $> .80$ is a very good absorber.

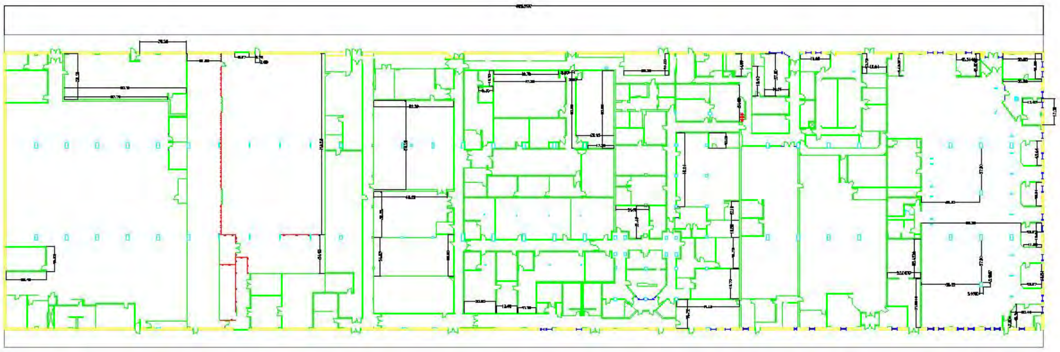
Sound Transmission Class (STC): A measure for rating the performance of a wall system as a barrier to airborne sound transmission between adjacent closed spaces, such as offices. A wall system with an STC < 35 is consider low performance, whereas one with an STC > 55 is high performance.

Utilization rate: Average area of workspace (including circulation, support and pro-rata share of special space) used by each person, measured in square feet or square meters. In Australia, referred to as accommodation ratio.

Vacancy rate: Percentage of building area not occupied or obligated compared to total building area leased or owned.

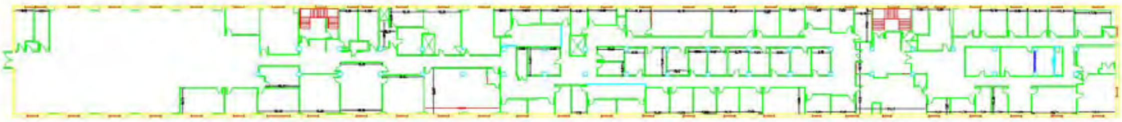
Appendix B: Floor Plans

Bldg 10280: Before



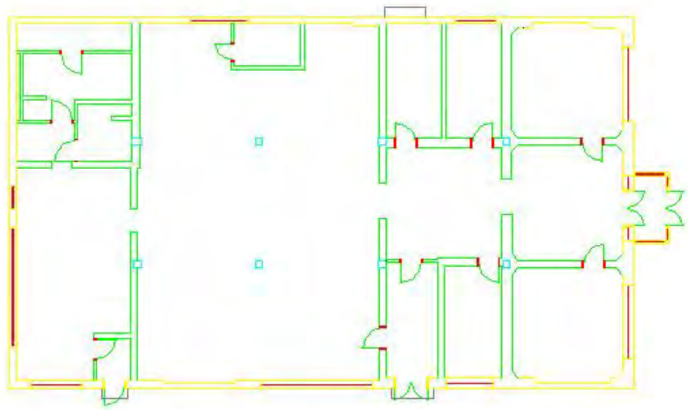
Bldg 10280: After

Bldg 20011: Before

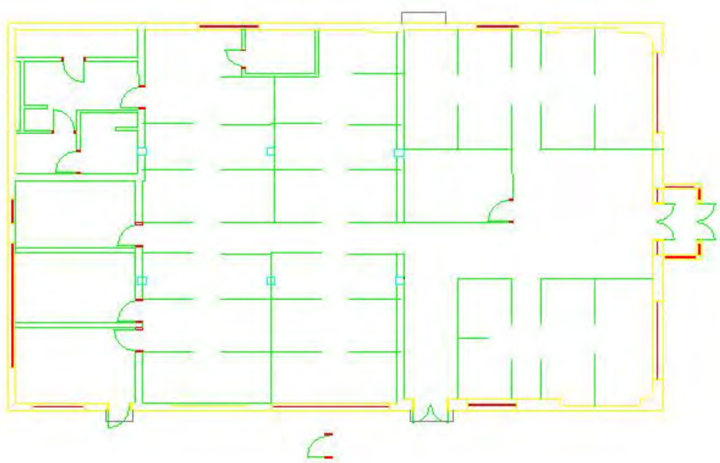


Bldg 20011: After

Bldg 20047: Before



Bldg 20047: After



Bldg 34006: Before

Bldg 34006: After

Bldg 34012: Before

Bldg 34012: After

Appendix C. Floor Plan Modification Log

The following is the methodology used to alter the floor plans listed in Appendix B. AutoCAD 2010 was the software used. Other software suites may differ slightly in method or terminology. Although there are many ways to alter the floors plans the following is a list of the general guidelines and considerations used to achieve the end result.

1. Identify facilities with the lowest building efficiency ratio below .7 and with the highest NSFPP greater than 200. These will be prioritized higher as potential candidates for modification.

2. Identify structural walls, wet walls, bathrooms, kitchens, plumbed areas, mechanical spaces, and any other areas within the facility that aren't easily relocated.

3. Alter the color or separate, onto a separate layer, those areas identified in step 2. Any disruption to these areas should be minimized in order to reduce project cost and shorten renovation duration.

4. Calculate the number and size of conference rooms for future reference. Consult with the users to determine if the current number and size is adequate. If no user data is available assume that an equivalent number and size should be placed in the new space.

5. Select 20% of hard walled offices already in existence to be kept for the final design. Ensure they are spread evenly throughout the facility and are appropriately placed based upon the overall facility population and areas with higher density. Attempt to keep offices that are located on perimeter or structural walls.

6. Alter the color, or place on a different layer, all hard offices that will be kept based upon the analysis conducted in step 5.

6. Remove curtain walls and other obstructions to continue to increase the amount of open floor space.

7. Relocate any other necessary items not explicitly listed to exterior walls where possible.

8. The floor plan should now be largely open with hard walled offices, conference rooms, mechanical spaces, and rest rooms pushed to the outside of the space. This provides a blank slate with the most flexibility possible.

9. Now evaluate the entrances to the facility. Determine optimal locations for primary entrances and circulation relative to facility shape, proximity to parking, ingress/egress, and foot traffic within the facility. Use existing entrances whenever possible to minimize renovation costs.

10. Remove lobbies and waiting areas from entrances that are no longer primary. This additional space can now be used as part of the open floor plan redesign.

11. Retain non-primary exits required for fire code and necessary egress. The goal is to make the primary circulation areas removed in steps 9 and 10 and transition them into secondary or emergency only circulation space. A narrower exit that meets fire code for egress will be far more spatially efficient than an entrance with a lobby or foyer.

12. Utilize unit manning documentation to determine the ratio of management and workers. Retain the appropriate ratio when adding offices but keep in mind that every manager doesn't automatically require a hard office. An enclosed office can be provided through systems furniture.

13. Utilize unit manning documentation and the job of the personnel housed to determine what, if any, personnel require hard offices based upon counseling, privacy, or security clearance.

14. Utilize unit manning documentation to determine the types of employees and their designated office size according to AFH 32-1084.

15. Evaluate the open floor plan for a modular furniture size that would meet the needs of personnel within the organizational hierarchy and also meet minimum office size requirements. Do not provide offices, hard or modular, in sizes that exceed AFH 32-1084 guidelines.

16. Rotate or rearrange cubicles to maximize the number that can be fitted. This may take several iterations with slightly different configuration of furniture.

17. If a unit has excess space leave it empty to be used by another organization. Try to consolidate all excess space into a single location so that flexibility to house additional groups is maximized.

18. Replace the conference rooms noted in step 4 and place in a more optimal location. Be sure to keep them the same size or slightly larger due to increased personnel.

19. Consider adding one or two additional conference rooms depending on personnel additions. This may require consultation with the end user to evaluate the requirement.

20. Consider loud equipment, conference rooms, and other high noise areas while developing the floor plan. Place loud items together and quieter office areas as far away as possible.

21. Create support space areas that house file storage, printers, information and technology equipment. Be sure to distribute them throughout the floor plan.

22. If the organization had any other special requirements necessary to conduct their job ensure they are placed back in the space. A determination on whether they should be hard walled or modular must be made based upon noise, function, location, cost, and the 80/20 open floor plan ratio.

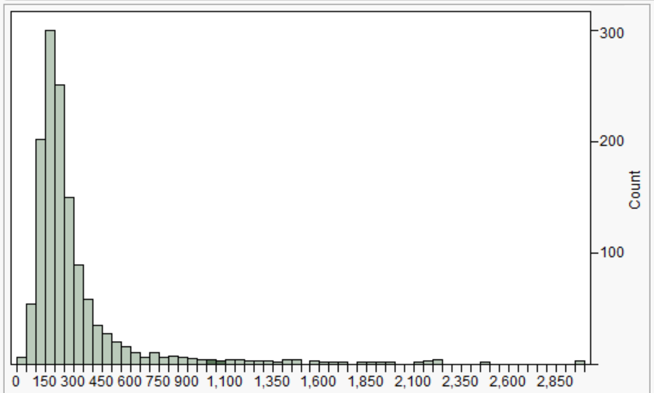
23. Ensure hallways remain a minimum of 6 feet wide or greater as required by fire code and maximum occupancy.

24. Although not covered by this thesis the lighting, HVAC, and fire suppression systems would need to be modified based upon the revised layout, local building codes, and the needs of the end user.

Appendix D. Statistical Analysis Output

Distributions

Column 1



Quantiles

100.0%	maximum	2979
99.5%		2201.28
97.5%		1191.2
90.0%		491.2
75.0%	quartile	304
50.0%	median	216
25.0%	quartile	161
10.0%		120
2.5%		85
0.5%		50.44
0.0%	minimum	21

Moments

Mean	293.84771
Std Dev	294.41132
Std Err Mean	8.2066373
Upper 95% Mean	309.94757
Lower 95% Mean	277.74784
N	1287
Sum Wgt	1287
Sum	378182
Variance	86678.028
Skewness	4.4337767
Kurtosis	25.39621
CV	100.19181
N Missing	0

Bibliography

Allen, Thomas. (1973). A Field Experiment to Improve Communications in a Product Engineering Department: The Nonterritorial Office. The Journal of Human Factors and Ergonomics Society. Vol 5, No 5, pp. 487-498.

American Institute of Architects. (2007). AIA Document D101. AIA Press. New York.

Assistant Secretary of the Air Force for Installations, Environment and Logistics (2010). Air Force Energy Plan. Secretary of the Air Force, Pentagon. Washington, DC.

Balboni, Barbara. (2011). *RS Means Square Foot Costs*. RS Means. Norwell, Massachusetts.

Becker, Franklin. (2001). Offices that Work: Balancing Communication, Flexibility, and Cost. Cornell University.

Becker, Franklin. (1995). Workplace by Design: *Mapping the High Performance Workscape*. Jossey-Bass. San Francisco.

Berkman, Elliot. (2012). A Conceptual Guide to Statistics using SPSS. Sage Publications. California.

Byers, Timothy A. (2010). S-File: Key to 20/20 by 2020 Success. *Air Force Civil Engineer*. 18(3), 5-10.

Chiddick, David. (2006). UK Higher Education Space Management Project: Promoting Space Efficiency in Building Design. Space Management Group. March, 2006.

Cole, R. (1999). Architect's Guide for Sustainable Design of Office Buildings. Public Works and Government Services Canada. British Columbia.

Culver, Michael. (2007). Transforming the CE Enterprise. *Air Force Civil Engineer*. 15(5), 4-12.

Defense Media Activity for the Secretary of the Air Force. (2011). Airman: The Book. AFD-110301-069. Retrieved on 5/31/11 from http://www.af.mil/shared/media/document/AFD-110301-069.pdf

Deputy Chief of Staff, Logistics, Installations and Mission Support (AF/A4/7). Air Force Infrastructure Energy Plan 2010. Washington: GPO, 2010).

Deputy of the Under Secretary of Defense. Base Structure Report Fiscal Year 2010 Baseline. Washington: GPO, 2010.

Dess, G. et al. (1999). Beyond Productivity: How Leading Companies Achieve Performance by Leveraging their Human Capital. American Management Association. New York.

Egan, David. (1988). Architectural Acoustics. McGraw Hill. New York.

General Services Administration. (2006). Real Property Performance Results 2006. Washington DC. GSA Office of Government-wide Policy.

General Services Administration. (1997). Office Space Use Review. Washington DC. GSA Office of Government-wide Policy.

Gerstner, Louis. (2003). *Who Says Elephants Can't Dance?* Harper Collins. New York.

Headquarters Air Force A7C. (2010). 2010 Almanac. *Air Force Civil Engineer*. 18 (4), 8-12.

Kumlin, Robert. (1995). *Architectural Programming: Creative Techniques for Design Professionals*. McGraw Hill. New York.

Liker, Jeffrey. (2004). *The Toyota Way: 14 Management Principles From the World's Greatest Manufacturer*. McGraw Hill. Wisconsin.

Locke, Edwin et al. (1981). Goal Setting and Task Performance. Psychological Bulletin. Vol 90, No. 1, 125-152.

Meller, R.D. (1996). Facility Layout Objective Functions and Robust Layouts. International Journal of Production Research. Vol 34, Vol 10. pp. 2727-2742.

McBain, John. (2009). Fit-up Standards: Technical Reference Manual. Public Works and Government Services Canada. British Columbia.

McGregor, Wes. (2000). Facilities Management and the Business of Space. Butterworth-Heinemann. Burlington, MA.

Office of Planning and Budget. (2001). Guidelines for Predesign of Major Capital Projects. Georgia State Financing and Investing Commission. Retrieved on 1/18/11 from http://opb.georgia.gov/vgn/images/portal/cit_1210/14/28/162041300 predesign_guidelines_april_2001.pdf.

Pena, William. (2001). *Problem Seeking: An Architectural Programming Primer*. Wiley and Sons. New York.

Public Works and Government Services Canada. (2000). The Environmentally Responsible Green Office at a Glance. Public Works and Government Services

Canada. British Columbia.

Senge, Peter M. (1990). *The Fifth Discipline*. New York: Doubleday & Co.

Space Management Office. (2007). Building Efficiency Ratio Guidelines. University of New Mexico. Retrieved on 3/11/11 from http://iss.unm.edu/PCD/SM/doc/ Building%20Efficiency%20Ratio%20Guidelines.pdf.

Steelcase. (2009). Space Standards Among Large Corporations. Steelcase. Michigan.

Steiner, Jon. (2005). The Art of Space Management: Planning Flexible Workspaces for People. *Journal of Facilities Management*. Vol 4, No. 1, 6-22.

United States Census Bureau. (2009). Federal Government Civilian Employment. Washington DC: US Government Printing Office.

United States Department of Agriculture. (2006). Space Planning Policy Service First Collocation and BLM OR/WA Space Policy. United States Department of the Interior, Bureau of Land Management. Retrieved 1/9/11 from http://www.fs.fed.us/servicefirst/docs/collocation-space-planning-policy.pdf

United States Department of Defense. (n.d.) DOD 101: An Introductory Overview of the Department of Defense. Retrieved 2/24/11 from the DOD website: http://www.defense.gov/pubs/dod101/dod101.html

Weinberg, Sharon. (2008). Statistics Using SPSS: An Integrative Approach. Cambridge University Press. New York.

Womack, James and Jones, Daniel. (2003). *Lean Thinking.* Free Press. New York.

Vita

Captain Jared Maline graduated from Kenmore West High School in Kenmore, New York. He entered undergraduate studies at Virginia Tech in Blacksburg, Virginia where he graduated with a Bachelor of Architecture Degree in May 2003. He entered graduate studies at Western Carolina University in Cullowhee, North Carolina where he received a Masters of Project Management in December 2008. He was commissioned through Officer Training School in Montgomery, Alabama.

His first assignment was at Bolling AFB where he served in a number of project management roles as well as Chief of Readiness. While stationed at Bolling AFB he deployed in 2005 as Lead Engineer for New Horizons in La Ceiba, Honduras. In 2007 he deployed as the Base Antiterrorism Officer for Bagram Airfield in Afghanistan. In August 2008, he was assigned to the 4th Civil Engineering Squadron. Seymour Johnson AFB, North Carolina where he served as the Chief of Operations Support. While stationed at Seymour Johnson he deployed in January 2010 to spend six months at Al Udeid Air Base, Qatar as the Programs Flight Chief. In August 2010 he entered the graduate School of Engineering Management, Air Force Institute of Technology. Upon graduation, he will be assigned to the Pentagon.

REPORT DOCUMENTATION PAGE	*Form Approved OMB No. 074-0188*

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of the collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE *(DD-MM-YYYY)*
23-03-2012

2. REPORT TYPE
Master's Thesis

3. DATES COVERED *(From – To)*
Aug 2011 –Mar 2012

4. TITLE AND SUBTITLE
Reducing Operating Costs by Optimizing Space in Facilities

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Maline, Jared J., Capt, USAF

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)
Air Force Institute of Technology
Graduate School of Engineering and Management (AFIT/EN)
2950 Hobson Way, Building 640
WPAFB OH 45433-7765

8. PERFORMING ORGANIZATION REPORT NUMBER
AFIT/GEM/ENV/12-M14

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Intentionally left blank

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A. Approved for Public Release; Distribution Unlimited

13. SUPPLEMENTARY NOTES
[The Disclaimer on the second page of your thesis needs to go here!!!]

14. ABSTRACT
Facility and maintenance costs represent a large portion of the government's expenditures and need to be reduced to meet energy efficiency goals as well as ensuring fiscal responsibility from the government. The purpose of this research was to determine which factors are important to space optimization in office buildings. An analysis and grading scale was developed for current and proposed utilization rates for the Air Force's inventory. The culmination of this research was the development of a metric to evaluate spatial efficiency in current facilities and set standards for futures buildings. The potential savings are highlighted using Air Force Real Property inventory as a case study. Cost savings were calculated based upon cost data collected by the U.S. General Services Administration and Reed Construction Data.

15. SUBJECT TERMS
Space optimization, Building efficiency ratio, Energy reduction, Utility reduction

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON / 19b. TELEPHONE NUMBER *(Include area code)*
U	U	U	UU	69	Lt Col William E. Sitzabee AFIT/ENV (DSN) 785-3636, x 7395, William.Sitabee@us.af.mil

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18