AN EVALUATION OF FACILITY MAINTENANCE AND REPAIR STRATEGIES OF SELECT COMPANIES

THESIS

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AFIT/GEE/ENV/02-19

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Although initial construction costs are high, the cost of operation and maintenance over a facilities life-cycle is significantly higher. A common challenge for facility maintenance professionals is balancing the cost of facility Maintenance and Repair (M&R) with the benefits derived from those facilities. This thesis documents how a selection of companies implemented that balance by determining their facilities requirements based on their chosen facility condition level and how they then allocated funds. The research effort consisted of interviews with facility maintenance professionals at each company selected. The data was then used to perform a multiple case study analysis and comparison with the methods currently used by the USAF.

Results indicate that companies that methodically identified their requirements and used those requirements as the basis for allocating funds to meet those requirements incurred the least impact from facility problems on their daily operations. In comparison, companies that allocated funds based on methods other than M&R requirements typically under-funded those requirements, resulting in facilities that did not meet their needs, required work around conditions, and increased their cost of doing business. Finally, the data suggests that a commitment to facility maintenance does not impede a company's ability to compete within their market.

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THESIS

Presented to the Faculty of the

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Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Engineering and Environmental Management

Christopher L. Sharp

Major, USAF

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Degree of Master of Science in Engineering and Environmental Management

Brig Gen David M. Cannan Member	Lt Col Wm. Brent Nixon Member
Lt Col Heidi S. Brothers Chairman	William T. Marsh Member

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Abstract

Whether a company is predominantly administrative or production oriented, facility related costs are usually a significant portion of the overall cost of doing business. Although initial construction costs are high, the cost of operation and maintenance over a facilities life-cycle is significantly higher. A common challenge for facility maintenance professionals is balancing the cost of facility Maintenance and Repair (M&R) with the benefits derived from those facilities. This thesis documents how a selection of companies implemented that balance by first determining their facilities M&R requirements based on their chosen facility condition level and how they then allocated funds to meet those requirements. The research effort consisted of interviews with facility maintenance professionals at each company selected. The data was then used to perform a multiple case study analysis and comparison with the methods currently used by the USAF.

Results indicate that companies that methodically identified their requirements and used those requirements as the basis for allocating funds to meet those requirements incurred the least impact from facility problems on their daily operations. In comparison, companies that allocated funds based on methods other than actual facility M&R requirements typically under-funded those requirements, resulting in facilities that did not optimally meet their needs, required extensive work around conditions, and ultimately increased their cost of doing business. Finally, the data also suggests that a commitment to proper facility maintenance does not impede a company's ability to compete within their chosen market.

AN EVALUATION
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OF
SELECT COMPANIES

I. Introduction

General Issue

The United States Department of Defense (DoD) currently maintains the largest real property inventory of any single organization in the world. This inventory consists of the land, buildings, roads, runways, and utility distribution systems that make up the installations, posts, and ports of the various branches of the military. The value of this property is estimated to exceed $500 billion. Of this amount, the United States Air Force (USAF) is responsible for 30% of the total DoD real property inventory, an estimated value of $146.4 billion (U.S. General Accounting Office, 1999: 4, 56).

The buildings, roads, runways, and utilities are the result of capital investment and are classified as improvements to the natural value of the parcels of land on which the military installations are located. The values of these improvements are referred to as the Plant Values (PV) and account for the major portion of the total real property value (U.S. Department of Defense, 1989: 27).

Figure 1 provides a visual representation of the PV vs. Total Property Value. PV includes all improvement costs such as the buildings, utility systems, roads, and other infrastructure necessary to carry out the activities of that plant. PV intentionally excludes the value of the land where the plant is located due to the wide variation of value, which is

dependant on location, population density, and esoteric measures such as view. Total property value is the value of the land plus the value of the PV. This differentiation allows PV to be used as reasonable estimate of the value of the property improvements alone.

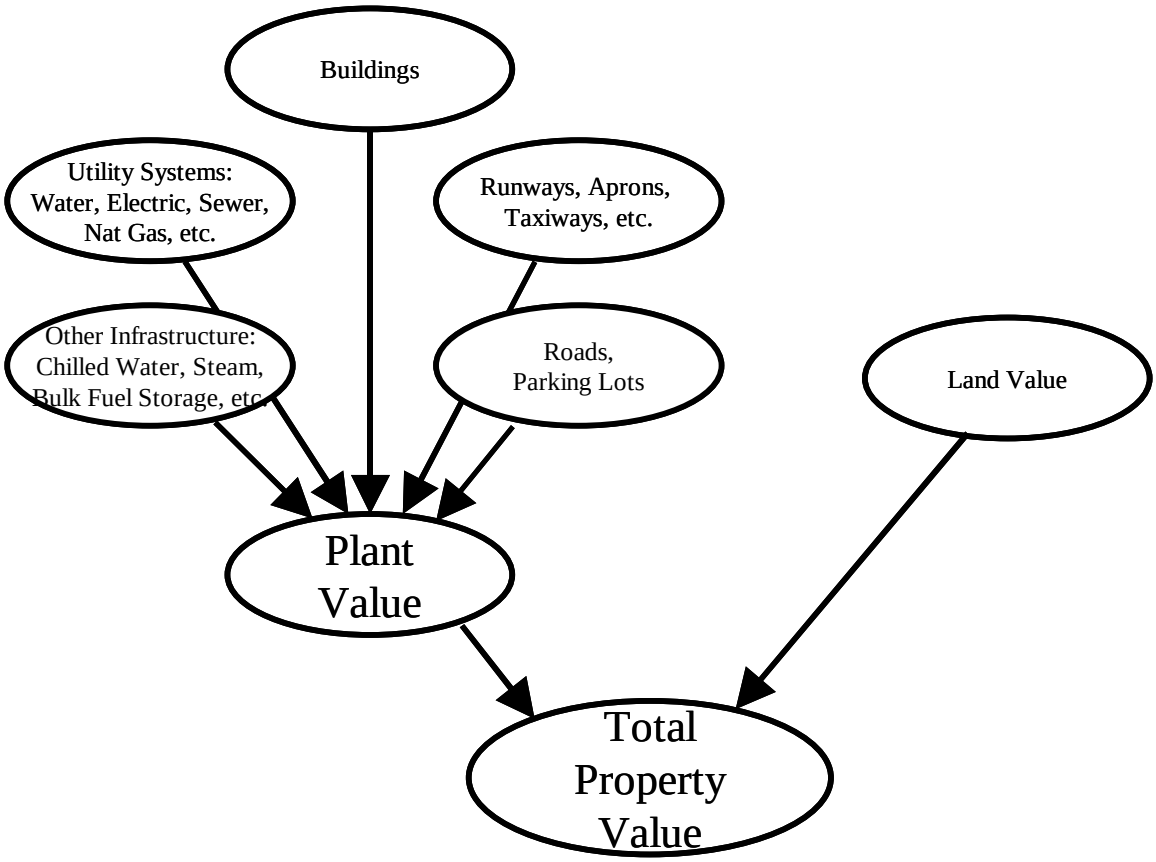

Figure 1. Plant Value vs. Total Property Value

Scheduled maintenance and unscheduled repairs are required to prevent rapid deterioration of this large facility investment. The Civil Engineering Research Foundation published a study entitled *Level of Investment Study: Facilities and Infrastructure Maintenance and Repair* in 1996. This study was based on the results of a self-administered survey, which was returned by twenty-nine institutions, such as

airports, private companies, and universities, in which they reported their funding level as a percentage of PV. The survey results indicated that the USAF was investing at a comparable rate. However, the report went on to state:

> …none of the organizations reported whether or not their (level of investment) was adequate or appropriate for maintaining their infrastructure (Civil Engineer Research Foundation, 1996: 39).

Similarly, the Building Research Board (BRB) of the National Research Council (NRC) documented that managers of public buildings and elected officials find it easy to neglect the maintenance requirements of the facilities for which they are responsible. The report states that the practice has become so prevalent that under-funding of maintenance and repair (M&R) has become "a de facto policy that each year compounds the problem as the backlog of deficiencies grows." The report presents evidence that managers who neglect facility maintenance cause the facilities to reach the end of their life cycle prematurely, thus requiring additional investment through renovation or complete replacement earlier than would be otherwise required. The report then states:

> Decisions to neglect maintenance, whether made intentionally or through ignorance, violate the public trust and constitute a mismanagement of public funds. In those cases where political expediency motivates the decision, it is not too harsh to term neglect of maintenance as a form of embezzlement of public funds, a wasting of the nation's assets (Building Research Board, 1991: 1-2).

Although a strong statement, a valid point is made: Managers responsible for an organization's well-being and assets, should also be held accountable for the long-term condition of their facilities.

Like their civilian counterparts, facilities managers within DoD were also concerned with the impact of deferred facility maintenance and initiated a study in the mid 1980s. The results of this study were published in 1989 as a report entitled *Renewing the*

Built Environment, which documented the investment rate for a sample of colleges and universities, sixteen major private corporations and twenty-three non-DoD government entities.

The results of this comparison are shown in Table 1. DoD was documented to have invested 1.6% of its plant replacement value for construction (CNSTR) and 1.4% for M&R, resulting in a total investment of 3.0%. Comparatively, Major Colleges and Universities invested 6.9% in construction and 1.5% in M&R for a total investment of 8.4% of their plant replacement value. Sixteen major private coproations invested 5.4% in new construction and 3.5% in M&R, for a total investment of 8.9% of their plant replacement value. Finally, 23 Non-DoD Governmental entities were documented as investing 8.2% in construction and 1.4% in M&R for a total of 9.6% of their plant replacement value. The DoD investment rate appeared to compare favorably with the other entities studied for M&R investment rates; however, DoD invested significantly less than the others in construction. This resulted in the total facility investment rate falling significantly behind the other organizations involved in that study (U.S. Department of Defense, 1989: H16).

The authors of *Renewing the Built Environment* recommended that the M&R investment rate be increased to correspond more closely to industry standards. Additionally, they recommended a minimum investment rate not to fall below specific values. The minimum rate recommended for facility maintenance was 1.0% of the plant value for all USAF facilities taken in aggregate. Additionally, the recommended minimum annual funds allocation for facility repair requirements was 0.75% of the PV for a total M&R investment of 1.75% of PV (U.S. Department of Defense, 1989: 30-31).

These minimum values were accepted as the funding allocation level and were still valid during this research effort (Marsh, 2000).

Table 1. Annual Facilities Construction vs. Maintenance & Repair Investment

(Based on Constant FY87 Dollars)

	Percent of Plant Replacement Value		
	CNSTR	M&R	Total
Department of Defense (DoD)	1.6%	1.4%	3.0%
Major Colleges & Universities	6.9%	1.5%	8.4%
Sixteen Major Private Corporations	5.4%	3.5%	8.9%
Twenty three Non-DoD Governmental entities	8.2%	1.4%	9.6%

(U.S. Department of Defense, 1989: H16).

Background

Publication of *Renewing the Built Environment* led Congress to become concerned that the military was not adequately verifying the requirements for the Real Property Maintenance Activities (RPMA) that were being reported to them. The DoD 1989 Appropriations Bill stated:

> "The committee is also concerned that despite DoD's interest in reducing depot maintenance and real property maintenance backlogs, the backlogs are not noticeably different from previous years. The Committee directs the Department to review the system used to determine the backlogs in depot and real property maintenance in an effort to produce verifiable backlogs rather than "paper" backlogs that are adjusted each year based on funding, rather than actual inventory. The Department should keep the Committee informed of its progress with this review and subsequent development of a more accurate system." (U.S. Department of Defense, 1989: 2 - 3]

Additionally, the Senate Appropriations Committee stated that there was limited scrutiny of the installationM&R requirements, which resulted in installationcommanders

placing "… sailing marinas and dog kennels among the backlog priority requirements" (U.S. Department of Defense, 1989: 3).

In response to this criticism, the USAF implemented the Commanders Facility Assessment (CFA) in 1993. The purpose of the CFA was to link facility performance directly with mission requirements. It required installation maintenance personnel to assess the condition of their facilities and rank the impact of that condition on the mission. The installation commander then certified the assessment as the bona fide requirement (U.S. General Accounting Office, 1999: 56 - 57).

However, the CFA had two problems. First, the rating criteria used by the assessors was subjective and varied from installation to installation, which permitted excessive latitude in the interpretation of facility conditions. Second, the CFA required the grouping of requirements by facility category resulting in lower-impact requirements being placed in the same category as critical requirements. These two problems reduced the credibility of the CFA with senior Air Force leadership (Marsh, 2000).

The CFA was replaced with the Facility Investment Metric (FIM) in 1998 (U.S. General Accounting Office, 1999: 57). Like the CFA, the FIM was intended to be a requirements identification tool that focused on the impact of a facility on the installations mission. The FIM rated individual projects as opposed to the system or facility rating used in the CFA. This allowed the engineering staff to identify specific requirements with an appropriate priority rather than having that requirement masked by a facility that was in otherwise adequate condition. The overarching principle of the FIM was to "… advocate for the level of funding necessary to address the most urgent facility needs of the Air

Force" by linking the funding of real property major repair and minor construction projects to the most urgent requirements of the USAF (U.S. Air Force, 1999a: 1).

During this time period, DoD began to focus on the real property maintenance activities across all of the services. A problem they found was the lack of common standards among the military services (U.S. Department of Defense, FCFH, 2000: 2). The Air Force, Army, and Navy had developed different facility maintenance operations. These differences ranged from different terms for similar activities to completely different programs and classification systems. Additionally, none of the services had a formal program to plan and program for maintenance requirements (U.S. Department of Defense, 1989: 16).

To address these problems, DoD implemented the Facilities Sustainment Model (FSM) in April 2000 to work in conjunction with existing military services repair requirement identification programs such as the FIM. The FSM had two distinct goals. The first goal was to standardize the facility related accounting procedures across the services. The FSM required each branch of the DoD to adopt the standards common to the existing private-sector facility maintenance profession and to use the same criteria for all facility related activities. This ensured that common standards would be applied across the DoD, allowing senior decision makers to more easily recognize which requirements needed the most urgent attention. The second goal was to standardize the way facility maintenance costs were predicted. The FSM is designed to forecast the annual cost of maintenance requirements for facilities based on the type of facility, size, and other factors. These forecasted requirements are based on the average life expectancy for similar commercial facilities and equipment found in the private sector. It does not

address the cost associated with restoring aging facilities to a serviceable level (Marsh, 2000).

At the time of this research, FSM was still being implemented. The adoption of existing industry standards and the consistent implementation of those standards across the DoD should provide an accurate estimate of the cost to maintain DoD facilities. During the implementation phase, adjustments to the program were to be made as needed to make it a complete and thorough tool for estimating the cost of annual facilities maintenance requirements.

In summary, the USAF and DoD have made great strides in the identification of facility maintenance and repair requirements. At the time of this research effort, the USAF used the FIM to identify existing facility repair requirements and the FSM to forecast facility maintenance costs over a facility's designed life cycle. Together, FIM and FSM were planning tools that adequately identified existing repair requirements and projected future maintenance costs, the total facility M&R requirement.

Although the current practices in use by the DoD are recognized as being improved over previous methods, no comparison has been made to determine how they compare with practices used by the commercial sector. Companies that have successfully competed in the open market may have facility M&R requirements identification and allocation methods that have contributed to their success. An examination of these companies may provide ideas that could be implemented by the DoD or suggest similar methods that could be adopted or modified for use to improve the DoD facility M&R management processes.

Problem Statement

This thesis documents how selected successful companies determined their facilities M&R requirements and how they then allocated funds to meet those identified requirements. This overall problem is broken down into three distinct questions:

- How did these companies determine the required M&R activities?
- How did these companies allocate funds to meet those identified requirements?
- How did these companies incorporate the life cycle cost and future capitalization of existing or new facilities in their overall M&R program?

Research Objectives

The following objectives were used for guidance in answering the research questions:

- Examine the methods these companies use to identify their M&R requirements
- Examine the methods these companies use to allocate funds to meet the identified M&R requirements
- Examine the role that capitalization plays on these companies M&R programs
- Document the "best practices" used by these companies
- Compare and contrast these methods with the current USAF practices

Research Methodology

The objective of this thesis is to research and document the facility M&R programs used by select companies to determine the level of investment necessary to maintain their facilities at the quality level desired. The method to be used is outlined below:

- Develop a rigorous research method that is uniform between research subjects that describes the investigative process, lists specific questions, and maintains the researchers focus at each company.

- Identify appropriate companies, contact facility maintenance professionals from those companies, elicit the information as outlined in the case study protocol, gather and analyze the data.

- Investigate methods used to prioritize and allocate funds for facility M&R projects by select companies.

- Compare companies with each other and with the DoD and USAF.

- Conclude with recommendations for improvements to DoD and USAF methods.

A detailed synopsis of each step of this methodology is included in Chapter 3.

Scope of Research

This effort was limited to a study of how select companies identify facility maintenance and repair requirements and determine the level of facility investment necessary to meet those requirements while maintaining their position of leadership in the marketplace. Companies were selected for study from a pool of candidates developed from:

- Companies with a reputation for quality facilities known within the military facilities maintenance establishment

- Facilities maintenance professional organizations

- Companies listed on the Fortune 500.

Companies comparable in size to the USAF that emphasized the use of high technology in their operations and required highly skilled craftsmen were of particular interest. The number of companies included in this research effort was limited to five, all of which were located within 150 miles of Wright-Patterson AFB. Additionally, the

research was limited to interviewing the facilities maintenance professionals at one site for each company and therefore may not represent the facility maintenance program implemented across an entire corporation. A detailed description of the complete selection process is presented in Chapter 3.

Relevance

There are at least two primary groups to which this research effort is directly relevant. The first group is composed of both government and private industry facility maintenance professionals. The second group is the academic community at large.

This research is pertinent to government facilities maintenance professionals because it documents the current facility M&R policies in use by five successful corporations. Regardless of department, government organizations have facilities and infrastructure that require ongoing M&R activities and the innovations found in industry can often be successfully implemented by government organization. Military leaders responsible for facilities and infrastructure M&R in particular should find this research useful because it compares the impact of the FIM and FSM as used by the USAF to those five companies' programs. This comparison provides an opportunity to validate the effectiveness of those existing M&R programs as well as modify the existing programs to include methods similar in concept and operation to those found in industry. Similarly to governmental organization, private organizations may also benefit from an analysis of the practices in use by successful corporations.

The second group to benefit from this research effort is the academic community. First, this research effort documents the current facility M&R policy for five successful corporations. In so doing, this effort illustrates the implementation of several of the

concepts espoused by facility M&R academicians and documents their relative effectiveness. Additionally, this effort extends work of others and, as a minimum, adds another data point to the previous body of work on facility M&R methodologies.

Summary

This chapter provided an introduction to the issues surrounding the facility M&R investment funding strategies of select companies with exceptional M&R programs. A brief history of the techniques used by the USAF was presented and shortcomings of each were listed. Next, the Research Objectives used to direct the research were presented. Finally, the scope and potential relevance of the research was presented.

The Literature Review in Chapter 2 provides a detailed summary of the facility maintenance strategies commonly used by facility maintenance organizations in the corporate world as well as the military. Chapter 3 presents a detailed explanation of the methodology used for this research and an in depth review of the case study method. Chapter 4 provides a short history of each company researched, documents the requirements identification processes used and the methods used to allocate funds to those identified requirements, and analyzes how the methods used to identify requirements is related to the allocation methodology. Finally, Chapter 5 documents the case study effort, the lessons learned, and provides the results of this research effort for consideration by facility maintenance professionals.

II. Literature Review

Chapter Overview

This chapter provides a detailed review of the literature pertinent to this topic. First, terms common to the field of facility M&R will be defined. Several of these terms are unique to the DoD and/or USAF; however, most have counterparts in the private sector that are very similar if not exactly the same. Next, the primary methods of determining the appropriate level of funds allocation for M&R as used throughout the facility maintenance profession will be discussed. This will be followed by an in-depth presentation of USAF and DoD methods for identifying M&R requirements and allocation of funds to meet those requirements.

Definitions

Within the professional facility maintenance career field, common terms are often used interchangeably and their meaning must be interpreted based on the context used. As an example, the term M&R may be interpreted as any maintenance activity, repair activity, a project that is a combination of both, or something altogether different, depending on the person using the term and the context in which it was used. To avoid confusion, the definition of several key terms used throughout this effort follows.

Exceptional Facility Investment Program

The goal of this research is to documents how five successful companies determine their facility M&R requirements and how they then allocate funds to meet those identified requirements. The methods used by these companies could then be compared and

contrasted with an “exceptional” or “ideal” facility investment program, allowing an objective analysis of each method referenced to an identical standard. Unfortunately, no such definition of an exceptional facility investment program was found in the existing literature. Therefore, a definition based on concepts and principles commonly accepted within the facility maintenance profession will be developed.

Consider a company that repairs pumps in a machine shop. If this company only complies with OSHA regulations and performs the minimum facility M&R required, it may or may not qualify as a company having an exceptional facility investment program. Similarly, if this company maintains facilities in near-perfect condition, it may or may not qualify as a company having an exceptional facility investment program. The resulting facility condition alone does not determine whether the company has incorporated an exceptional facility maintenance program or not. Rather, the process used by the company to arrive at an appropriate facility condition is the basis for the definition.

For the purpose of this research, an exceptional facility maintenance program incorporates each of the following principles:

- An acceptable level of facility quality standard has been pre-determined. This level may be an absolute or a variable dependent on the type of work performed, corporate policies, etc.
- A method to determine facility M&R requirements had been developed.
- A method to allocate funds to meet those identified requirements has been developed.
- Actual facility quality is compared to the pre-determined standard and facility M&R efforts are implemented to meet or exceed the standard.

The emphasis of an exceptional facility maintenance program is on the process used rather than the end results and therefore does not require facilities to be maintained in

"perfect" or "as-new" condition. It succinctly defines the desired facility quality level to meet underlying organizational goals, such as maximizing productivity, minimizing cost, reducing waste, reducing pollution levels, etc. Facility M&R requirements necessary to meet those goals would then be methodically identified. This company would also have a fiscal policy in place that used those identified requirements to not only estimate required costs but also allocate funds to meet those requirements. All facility M&R activities would be performed taking into account the facility's anticipated life span and future facility capital investment requirements. The resulting facility would be one that is ideal for the work performed, maximizing productivity while minimizing down time due to facility M&R problems.

Work Classifications

Competitive organizations, whether public, private, or governmental, use some reasonable technique to account for the work performed. Since facility and infrastructure costs are often a significant portion of an organization's physical investment, most extend some method of accounting to their facilities management efforts as well. Within the USAF, this activity is performed by the civil engineer organization using work classifications to account for the various activities. Work classifications used by the USAF and DoD include Maintenance, Repair, Minor Construction (MC), Renovation, and Military Construction (MILCON) (U.S. Air Force, 1999a; 8).

Work classification by activity type is useful for providing an organization's managers with an impression of the plant condition. Increased M&R costs indicate aging facilities and equipment. These costs can then be analyzed and compared to the cost of bringing the facility back to like-new condition or complete replacement to determine the

most economical method to keep the equipment and facilities operational. Additionally, this data can be used to forecast maintenance budgets.

The DoD has an additional accountability requirement: Congress requires justification of how all funds will be used prior to making the appropriations and an accounting of how those funds were actually used after they have been expended. Congress has dictated that the justification and accounting both indicate what type of activity the funds are for (D'Angelo, 1997: 16).

Maintenance and Repair

The Building Research Board defined maintenance as: " the upkeep of property and equipment, work necessary to realize the originally anticipated useful life of a fixed asset" (Building Research Board, 1990: 3). Similarly, the USAF defines maintenance as "…work required to preserve real property and real property systems or components and prevent premature failure or wearing out of the same."(U.S. Air Force, 1999a: 11] Both of these definitions focus on a specific element of the work being undertaken. Specifically, the work must preserve existing property or be necessary to achieve the designed useful life. In essence, maintenance involves preventive activities necessary for the long term care of the facility system.

Repair is defined as "… restoration of a facility or component thereof to such a condition that it may be effectively utilized for it's designated purposes . . ." (Federal Facilities Council, 1996: 8). The USAF defines repair in similar manner:

> Repair means to restore real property and real property systems or components to such condition that they may effectively be used for their designated functional purposes (U.S. Air Force, 1999a: 11).

The recurring theme in both of these definitions is restoration of a system to a level appropriate for the designated purpose. Therefore, repair activities are restorative or curative in nature.

Comparing the definition of maintenance to the definition of repair, a significant distinction becomes evident: maintenance is a preventative activity necessary to achieve the systems designed lifespan, whereas repair is a restorative activity necessary to return the system to an effective operational level. Because of its preventive nature, system providers often recommend a maintenance schedule and it is, therefore, relatively easy to forecast future costs for maintenance activities. On the other hand, repair activities are not necessary until a system failure or degradation is identified. Depending on the severity of the problem, the required repair may disrupt the organizations production, resulting in higher costs, lowered work productivity, and increased delays. For this reason, the cost of maintenance is often justified as offsetting the higher cost of repairing a given system or equipment item (U.S. Department of Defense, 1989: 22, 23).

Construction

Construction, as defined by the USAF means, "…to build, develop, convert, or extend real property and real property systems or components (U.S. Air Force, 1999a: 16)." To comply with Congressional mandates, the DoD also differentiates between two levels of construction investment. The first work classification for construction as used by the military is minor construction (MC). MC includes all facility costs for any project other than those specifically classified as maintenance or repair. MC projects may not exceed a pre-determined threshold, which, at the time of this research, was established at

$500,000. MC work is funded by the Operations and Maintenance (O&M) line item in the Defense Appropriations bill (U.S. Air Force, 1999a: 21).

The second work classification for construction as used by the military is Military Construction [MILCON] and includes "…any construction, development, conversion, or extension of any kind carried out with respect to a military installation…" with costs in excess of $500,000 (U.S. Air Force, 1994a: 16). MILCON is the primary method by which the DoD capitalizes facility investment. The high costs associated with MILCON projects, coupled with the public disclosure of the details of these projects, usually results in a high profile project with intense interest from the political leaders from the area where the project is to be constructed.

Concepts

This section presents several concepts used by facility managers. First, the concept of capitalization will be presented. This is followed by a presentation of the concepts of facility requirements identification and funds allocation.

Capitalization

The term "capitalization" as used by accountants has a specific meaning. The root word "capital" is defined as "The total amount of money or other resources owned or used to acquire future income or benefits (Skousen, 1999: B-3)." Capital assets are defined as the "Long-term assets, such as property, plant, and equipment, that require significant investment of capital (Skousen, 1999: B-3)." For the purposes of this research effort, "capitalization" is defined as the act of investing capital assets for the construction of new facilities or major repair of existing facilities with the intent of gaining long-term benefit from those facilities.

Requirements Identification vs. Funds Allocation

The USAF differentiates the identification of facility M&R requirements from funds allocation for those requirements that have been identified. The requirements identification phase is the discovery and documentation of facility needs or defects. The allocation phase is the distribution of funds to meet facility requirements (Marsh, 2000).

Methodology Categories

Facility maintenance experts have developed different methods of determining the appropriate maintenance funding levels, each unique to a particular need or point of view. According to research performed by Ottoman, these methodologies can be grouped into four general categories: Plant Value Methodologies, Condition Assessment Techniques, Life-Cycle Cost Methodologies, and Formula Budgeting Methodologies. (Ottoman, 1997: 9-10]

Plant Value Methodologies

Plant value (PV) can be determined by two methods. The first method is based on the use of unit cost factors and defines PV as the "cost to replace the facility with one of equivalent capacity and function" (Barco, 1994: 29). This is the preferred method of assessing PV for USAF facilities as it provides a reasonable estimate for the cost of replacement with a modern facility that meets the requirements as well as complying with modern building codes.

The second method is used when unit cost factor information is not available for a particular facility type. In these cases, the original cost of construction is adjusted for inflation, improvements, capacity changes, etc. (Barco, 1994: 29).

Maintenance professionals who use the PV method have observed that it "gives an indication of the size of the inventory and also the sophistication of the technology employed…"(U.S. Department of Defense, 1989: 27). PV methodologies are thus based on the assumption that the size and complexity of a facility is an accurate indicator of the average M&R requirements.

PV is best used as a tool to program for long term allocation. It does not account for any actual M&R requirements, rather, it rationalizes that a certain level of funds allocation is required for the aggregate of facilities within an organization. Given that an appropriate percentage is used for the calculation, PV can allow planners to estimate future maintenance fund allocation needs with little data.

Condition Assessment Methodologies

The Condition Assessment Methodology, also referred to as the Condition Assessment Technique (CAT) by many facility M&R professionals, is used to determine the current condition and value of the existing real property. It also is used to program future maintenance funds to keep real property at the desired quality level. Within the facility maintenance profession, two CAT methods are commonly used.

The first method is used to determine the appropriate M&R budget based on an assessment of a facilities' condition. This assessment is usually a physical inspection of the facilities and may include the use of checklists and subjective assessment by the inspection team. This is followed by cost estimates to perform the necessary M&R for the assessed deficiencies (Civil Engineer Research Foundation, 1996: 18). This method focuses on immediate and deferred maintenance needs (Melvin, 1992: 22).

The second method uses a different approach to accomplish the same objective. The facility requirements of the using organization are analyzed in view of any special use requirements or expected length of time of occupancy. The facilities to be used by the organization are then assessed in light of these long-term requirements. Identified M&R requirements are then planned and programmed. The focus of this method is on long-term planning and prediction (Melvin, 1992: 22] and is also used to forecast capitalization requirements (Civil Engineer Research Foundation, 1996: 18).

CAT is used for M&R requirements identification and allocation. Although useful for short-term needs, CAT can be used to predict long-term requirements such as the expected remaining life of an equipment item.

Life Cycle Cost Methodologies

Life Cycle Cost (LCC) methodologies are based on the concept that future M&R requirements for a facility can be predicted by breaking down a facility into its systems and components and applying life expectancy or life-cycle concepts to those systems and components (Melvin, 1992: 48). This method predicts the frequency of repair or replacement for the various systems that comprise a facility and forecasts an expected future cost. A schedule for those activities is then planned and appropriate funds are programmed from the outset.

Although generally considered a unique methodology, LCC is similar to CAT methodologies that predict long-term requirements. Specifically, LCC is used for identifying M&R requirements over the entire life cycle of the facility, including design, construction, maintenance, repair, operation, and eventual demolition costs.

LCC can be used to forecast maintenance requirements. When coupled with reliable cost data, allocation can be planned in advance with relative accuracy.

Formula Budgeting Methodologies

Formula budgeting methodologies are attempts to combine the best of the other three methodologies. Proponents of formula budgeting methodologies have confidence that the cost of facility M&R can be predicted using an appropriate formula. Budget formulas are "sets of statements that detail a procedure for using predetermined fixed factors to manipulate variable data applicable to an institution in order to determine future funding requirements" (Monterecy, 1985: 17). In short, a formula can be devised that considers certain facts about a facility or facilities to determine the level of funds necessary for M&R activities short of actually estimating and documenting the cost of each requirement.

The actual methods used vary widely from single-variable formulas to complex, multiple-formula algorithms using multiple variables (Ottoman, 1997: 12). The variables used within the formulas also range from easily evaluated physical attributes such as the number of square meters of heated space to facility attributes that are less easily quantified such as the climate and the type of construction used. The fact that any number of variables may be used provides FB much flexibility, allowing it to be tailored to forecast requirements or allocate funds for construction, maintenance or repair.

Summary of Methodologies

The four primary methodologies used for facility M&R requirements identification and allocation were presented and the strengths and weaknesses of each were identified. The four methodologies were Plant Value (PV), Condition Assessment (CAT), Life Cycle

Cost (LCC), and Formula Budgeting (FB). Each of these four methodologies can be used for requirements identification (RI) or funds allocation (FA) for construction, maintenance, or repair work classifications; however, each is better suited for particular uses. The discussion presented for each of the four methodologies is succinctly presented in Table 2.

Table 2. Comparison Of The Four Basic Methodologies

	Construction		Maintenance		Repair	
Methodology	RI	FA	RI	FA	RI	FA
Plant Value (PV)				X		
Condition Assessment (CAT)			X	X	X	X
Life Cycle Cost (LCC)		X	X	X		
Formula Budgeting (FB)		X		X*		X*

* Dependant on variable selected for inclusion in the formula

USAF Methodologies

The USAF manages their real property investment using several of the methodologies described above. This section presents the methods used by the USAF facility maintenance professionals to perform the analysis, planning, & programming necessary to maintain the facilities and infrastructure for which they are responsible.

Facility Maintenance Practices

USAF facility maintenance professionals have long accepted that the best operational performance can only be achieved through well-maintained equipment and facilities. To achieve the facility condition necessary to maximize the operational capabilities, extensive Air Force Instructions (AFIs) were developed that present a thorough M&R program. A list of applicable AFIs is included in Appendix 5. The basis of the USAF facility M&R program was a scheduled preventive maintenance plan based on industry best practices, manufacturers recommendations, and historical records. The

preventive maintenance program was performed in conjunction with a facility repair program that included regularly scheduled facility inspections and proactive maintenance such as thermal imaging of electrical panels and overhead distribution systems. M&R requirements were tracked and scheduled using computer databases (Marsh, 2000).

Despite the design of the program, there were several issues that prevented USAF facility professionals from attaining the desired facility conditions. The primary reason for this failure was an inadequate level of funding to meet the identified facility M&R requirements. Although higher funding levels were identified as needed, the USAF implemented a funding level that was identified as a minimum requirement in 1989: 1% of PV for facility maintenance and 0.75% of PV for facility repair (U.S. Department of Defense, 1989: 30-31).

The funding level for facility M&R was then intentionally reduced by USAF decision makers. In an effort to implement a much needed force modernization program, the conscious decision to temporarily eliminate repair funding for two years was made in 1996. The original funding level was to be restored in 1998 with a promise to provide additional funding needed to make up for the two years of inadequate funding. Due to several competing requirements, the USAF was unable to restore funding to the facility M&R program as originally planned (Marsh, 2000).

Facility Requirement Identification

For facilities that have been in the inventory for some time, it may be necessary to perform a facility survey to determine what repairs are necessary to bring the facility into compliance with the current requirements. That is the position that the USAF found itself in during the early 1980s (Marsh, 2000).

During the 1980s, DoD went before Congress on multiple occasions to request additional funding to eliminate a growing backlog of facility repair requirements. These requirements were generated by the intentional decisions of senior military leaders to focus what funds were available on weapon system modernization programs (Marsh, 2000).

Congress provided additional funds. In the years that followed, however, military leaders continued to report that more were needed. Congress then began inquiring of how the previous funds had been spent to determine the true nature of the requirement and if the previously provided additional funds were used to fulfill true requirements. The GAO reported shortly thereafter that the funds were used appropriately and that the Military's procedures were better defined and more efficiently executed than non-DoD organizations (U.S. General Accounting Office, 1999: Executive Summary). However, some requirements were viewed as less than mission critical, even though they were accurately described requirements (Marsh, 2000).

Congress' inquiry into the militaries M&R expenses brought to light a significant problem in the facility maintenance profession. As M&R activities are deferred over time, a backlog of maintenance and repair (BMAR) requirements builds up. The BMAR of the 1980s directly resulted from the deference of M&R requirements following the end of the Vietnam conflict. BMAR accrues as the necessary M&R work is deferred (Marsh, 2000).

By their very nature, facilities, equipment, and machinery eventually fail. By definition, they will then require repair or replacement in order to function as originally designed. However, repair can often be avoided or deferred by using appropriate preventive maintenance proceedures. When maintenance is deferred, the facility more

rapidly degrades, eventually requiring a larger investment in repair costs than the maintenance costs would have been.

Commanders Facility Assessment (CFA).

In response to Congressional criticism, the USAF developed the Commanders Facility Assessment (CFA) in 1989. CFA was designed to be an identification tool for the requirements needed to adequately carry out the specific mission performed in a particular facility. The goal was to determine if the facilities in use met the mission requirements that they housed.

The conditions of the facilities at each USAF installation were determined by facility survey. Although the surveys varied by installation and Major Command (MAJCOM), teams consisting of facility maintenance professionals and the using agencies generally performed the surveys. These maintenance professionals were drawn from the installation's Base Civil Engineer (BCE) design staff and occasionally augmented by MAJCOM Directorate of The Civil Engineer staff members.

The surveys took the form of an initial review of the installation facilities, focusing on those facilities with a history of maintenance problems. Facilities identified as being deficient were then analyzed by a team, which walked through the facility documenting the condition of the facilities structure and equipment. The overall facility condition was then rated, based on the facilities ability to meet the requirements of the mission that it housed. The ratings ranged from Level I to Level III. That rating was then reviewed by the installation commander and certified as a true reflection of the facilities condition. This process certified deficiencies as valid requirements and rank ordered them from the least deficient to the most deficient (Marsh, 2000).

Level I rated facilities were those facilities assessed as unsatisfactory by the installation commander. These facilities provided minimal mission support, caused frequent mission interruptions, prevented some operations from occurring, and required work-arounds. Facilities with health and safety shortfalls were also rated as Level I. Additionally, any facility that required major upgrade within two years received a Level I rating (U.S. Air Force, 1994a: 17).

Level II rated facilities were those facilities assessed as degraded by the installation commander. These facilities provided impaired mission support, had negative effects on operations and/or morale, or often required work-arounds. Additionally, any facility that required a major upgrade within two to six years received a Level II rating (U.S. Air Force, 1994a: 17).

Level III rated facilities were all other facilities requiring repair but not assessed as a Level I or Level II. These facilities provided near adequate mission support, had a negligible negative effect on operations and/or morale, or occasionally required work-arounds (U.S. Air Force, 1994a: 17).

The CFA meets the requirements for classification as a condition assessment methodology (CAT). It involves a physical inspection of the facility using checklists and subjective assessments by an inspection team, focused on identifying the existing facility repair requirements. The inspection and documentation was then followed by cost estimates for the identified repair requirements.

Although the CFA was effective in identifying the facility deficiencies, several significant problems were identified shortly after implementation. First, CFA did not take into account the mission served by the facility in light of the overall installation mission.

Given two facilities that were equally deficient, a community support facility would be rank-ordered as a requirement equal to that of a primary mission facility (Marsh, 2000).

Second, CFA suffered from differing subjective ratings between installations and between MAJCOMs. No formal training was provided to ensure that personnel located at different installations used the same scale to differentiate a facility that was truly in poor condition from one that needed cosmetic renovation. This resulted in a rank order for each installation that accurately reflected the facility conditions on that installation, but could not be accurately compared between installations or MAJCOMs. Without standardization across the USAF, the "worst" facility on one installation could have been in better condition that another installation's "best" facility, yet still received immediate attention even though it was not actually the most urgently needed requirement from an Air Force perspective (Marsh, 2000).

The final problem was that the CFA was used in a manner inappropriate for its design. Although not designed as an allocation tool, it eventually was used as one. Funds were placed against facilities that were identified as not meeting the facilities mission requirements with out regard for how that facility's mission integrated with the overall installation or Air Force mission (Marsh, 2000).

Although the CFA method was implemented as directed from the Air Staff, these three problems together created a perception that the CFA was not a credible tool. In order to correct these problems, a new tool was devised: the Facility Investment Metric (Marsh, 2000).

The Facility Investment Metric (FIM)

The Facility Investment Metric (FIM) was established from the outset to correct the problems – both real and perceived – of the CFA. FIM was based on a concept called the Mission Area Rating Matrix (MARM). The MARM grouped all repair and minor construction projects according to mission area and impact on the installation's or tenant's mission. This two-dimensional layout not only helped decision makers characterize the types and significance of the unfunded requirements, but was also formed the basis for determining Facility Investment Indices (FIIs). MARMs helped make real property maintenance requirements readily identifiable to all levels of facility maintenance decision makers (U.S. Air Force, 1999a: 1-4).

There were several concepts unique to the FIM. The first was referred to as the Mission Area. Mission Areas grouped facilities according to their relationship to the overall installation and/or tenant's mission using the real property category codes. There were four Mission Areas:

> **Primary Mission:** Facilities and infrastructure that directly accomplish or directly support the installation/tenant's primary mission. Facilities that are categorized as Primary Mission Facilities include aircraft hangars, squadron flight rooms, control towers, and runways.
>
> **Mission Support:** Facilities that support the installation/tenant's primary mission, some infrastructure, and primary emergency response facilities. Primary emergency response facilities are limited to those facilities tasked to provide immediate life support and rescue service. Facilities that are categorized as Mission Support Facilities include the hospital, aircraft crash rescue facility, and utility distribution systems.
>
> **Base Support:** Facilities and some infrastructure that are not directly tied to the execution of the primary mission, but are necessary to keep the installation/tenant functioning properly. Facilities that are categorized as Base Support Facilities include the airman's dining facility, non-mission administrative offices.

> **Community Support:** Facilities that support the installation/tenant community. Facilities that are categorized as Community Support Facilities include the post office, commissary, officer and enlisted clubs, and the golf course (U.S. Air Force, 1999a: 1-4).

In facilities with multiple users, it was possible to have multiple Mission Areas according to their respective category codes.

Within each mission area, the facility requirements were rated based on their level of impact. There were three levels of impact:

> **Critical:** Significant loss of installation/tenant mission capability and frequent mission interruptions. Work-arounds are continuously needed. Risk Assessment Code (RAC) I or Fire Safety Deficiency Code (FSDC) of I. RAC I or FSDC I ratings are given to conditions that present serious safety or fire risk.
>
> **Degraded:** Limited loss of installation/tenant mission capability. Work-arounds to prevent mission disruption and degradation are often required. RAC/FSDC of II or III are included. RAC/FSDC II/III are violations of applicable safety and fire codes; however, they are less severe than a RAC/FSDC I rating.
>
> **Minimal:** Marginal or no adverse impact to installation/tenant mission capability. Work-arounds are seldom required. Included in this rating category are requirements that would improve the quality of life in work and living centers, improve productivity or lead to reduced operating costs. This rating also includes any requirement that does not meet the Critical or Degraded criteria (U.S. Air Force, 1999a: 1-4).

These two ratings – the mission area and the condition code – were used to calculate the hierarchy of importance for the facility requirement (U.S. Air Force, 1999a: 1-4).

A second concept was called the Facility Investment Index (FII). The FII was a set of indices used for analyzing the impact of funding decisions on the total facility inventory. The FII was calculated by summing the total dollar value of the facility requirements, then dividing by the PV. This value was then compared with previous

years' values to give an indication of the progress made in eliminating the backlog of facility repair requirements. Additional analysis could then be made by using the same technique with various combinations of categories within the MARM. For example, the FII for a specific mission area represented the total un-funded requirements in that specific mission area divided by the PV for that mission area (U.S. Air Force, 1999a: 9).

The FIM program functioned across all levels of management within the USAF facilities maintenance profession. The lowest level was the installation or tenant level. At that level, the Base Civil Engineer (BCE) was the installation commander's executive agent. The BCE ensured the Real Property records and electronic databases were properly updated by verifying that the Real Property category codes were correct for the facilities, verifying that the proper category codes were assigned to the correct mission area as listed in their respective Major Command's approved Mission Area List, and reviewing the electronic database to ensure projects were current and accurately justified. The BCE was also responsible for developing the installations MARMS. The BCE then transmited the information to the MAJCOM when required, usually on an annual basis. Although FII information specific to the installation could also be prepared, it was not required (U.S. Air Force, 1999a: 7).

The MAJCOMs role was one of quality control. They certified the installation submissions; extracted and forwarded tenant information to the appropriate parent MAJCOM, and submitted approved MAJCOM MARM data to the Air Staff. Additionally, the MAJCOM was required to maintain the Mission Area List, a definitive list of allowable mission areas. The Mission Area List tied specific infrastructure and facilities to the mission area they directly supported. They also were responsible for the

distribution of implementation instructions to their installations. The FII could be calculated by the MAJCOM; however, it was not required (U.S. Air Force, 1999a: 6).

The Air Staff used the MARM to develop the AF Facility Investment Strategy and Program Objective Memorandum (POM) inputs. The Air Staff approved all MAJCOM proposed changes to the Mission Area Lists, issued the annual and biennial FIM calls, calculated the FII, and provided feedback to the MAJCOMs (U.S. Air Force, 1999a: 5). A recent addition to this process was an annual Integrated Process Team meeting, which reviewed all "critical" ratings and their supporting justifications. This review was the primary method by which consistency across the Air Force was managed (Marsh, 2000).

Like CFA, FIM was not designed as an allocation method, although an allocation method was developed that closely followed the FIM ratings to ensure that mission critical facilities received the major portion of the funding allocation. However, the implementation of the allocation method was not mandatory and some installations and/or MAJCOMs chose to use other methods (Marsh, 2000).

The FIM may be classified as a condition assessment methodology (CAT). It involved a physical inspection of the facility using checklists and subjective assessments by an inspection team, focused on identifying the existing facility repair requirements. The inspection and documentation is then followed by cost estimates for the identified repair requirements.

Facility Sustainment Model (FSM)

CFA and FIM were developed to identify the facility restoration requirements of the existing USAF facilities and infrastructure inventory. However, there was no program in place to address the sustainment efforts needed to maintain the existing or new facilities

properly. Leadership within DoD realized this shortcoming and implemented the Facility Sustainment Model (FSM) in the spring of 2000. The FSM addressed several specific issues.

The first issue was that facility category codes were inadequate to the function for which they had been developed. Category codes were six digit numbers used to identify the function of a facility. The code was broken into a three-digit prefix and a three-digit suffix. The prefix defined the general use category such as administrative offices, hangar, or warehouse. The suffix further defined the use of the space (U.S. Air Force, 1999c: 141). For example, all USAF administrative facilities have the same three-digit category code prefix of 610. Specific administrative specialties such as a law center (610-112) were differentiated from other administrative offices such as the installation personnel office (610-128) by the use of a different three-digit suffix (U.S. Air Force, 1996: 171).

Unfortunately, the guidance for developing those codes had not been uniformly applied across the military services, resulting in categories that were not uniform among the services. The three-digit prefix used by the USAF for an administrative facility may not indicate an administrative facility in other branches of the service (Muchmore, 2000: 2).

An additional problem with this particular issue was that there were no standard units of measure, resulting in the same type of facility measured in differing ways, depending on the agency. For instance, warehouses were measured in square feet of floor space by one branch of the military and cubic feet of storage space by another. DoD analysts were unable to answer even simple questions such as how many square feet of a particular type of facility was in the DoD inventory (Muchmore, 2000: 2).

These issues prevented the DoD from analyzing DoD real property holdings and impeded implementing a realistic maintenance program for those facilities. FSM was implemented to solve those problems. First, a new six-digit category code system was developed. The result was the use of the same category codes for the same types of facilities across all branches of the DoD. These standardized category codes also used standardized units of measure. This standardization permitted meaningful analysis of DoD facilities across all branches of the services (Muchmore, 2000: 10).

Standardization across the services was only half of what FSM was designed for. Once a realistic and meaningful DoD-wide facility inventory was established, facility maintenance requirements could be accurately forecasted. Using the concept that facilities with similar classifications would be similar in design and construction, the team that developed FSM established that similar facilities would have similar M&R and construction costs. This realization provided an opportunity to develop a method of determining maintenance costs with a reasonable level of accuracy across the entire DoD (Muchmore, 2000: 2).

Cost data for facility maintenance were gathered from several sources. The primary source was standard, off-the-shelf, commercially published references (Muchmore, 2000: 12). In particular, *The Whitestone Building Maintenance and Repair Cost Reference* was used as a basis for many categories of facilities. This reference was based on facilities maintenance requirements research performed by Whitestone Research. Unique to this work was the set of 50-year cost profiles for individual buildings representative of 25 common building types. Whitestone also developed an integrated software package for use in conjunction with the reference (Lufkin and Silsbee, 1999: iii).

When industry standard references were non-existent for particular building types, costs were based on commercial factors for similar facilities, reinforced by service-validated cost factors. The method was used for unique facilities and calculated the maintenance cost by applying the ratio of maintenance costs to construction costs for similar facilities to the known construction costs of the unique facility (Muchmore, 2000: 12).

FSM was a requirements identifier that specified the expected cost for a facility's maintenance based on the construction methods, size, and intended use of the facility. Initial condition and age were not considered. This data was then matched with the appropriate facility model in the Whitestone reference, Means cost estimating handbook, or other reference. Methods unique to each of those references were then used to estimate the expected facility maintenance requirements (Marsh, 2000).

FSM was not without problems. For example, some unique military facilities did not fit the "standard" model. A good example of this problem would be facilities classified as a research laboratory with a large wind tunnel. The originally proposed model for a wind tunnel was a small facility that housed a portable or small permanently installed device. However, several USAF wind tunnels incorporate purpose-built laboratories with highly specialized aerodynamic and propulsion tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other highly specialized facilities. With such a broad range of wind tunnels types, a single category and average maintenance cost estimate was deemed unreasonable. At the time of this research effort, the FSM development and implementation teams were addressing this problem and others similar to it (Marsh, 2000).

Funds Allocation

At the time of this research effort, the USAF and DoD had developed well thought out methods to identify facility requirements. However, allocation procedures were not as refined. This section presents a basic description of the appropriation methods used by the US Federal Government, limitations placed on those funds by the US Congress, and then the particular methods in use at the time of this research effort to allocate funds from the initial Congressional appropriation, through the USAF Headquarters and MAJCOMs, down to the actual installations where the facilities were located.

Funds Sources

Funding for all branches of the US Federal Government had three distinct stages: budget development, enactment, and execution.

Budget development for the DoD was a complicated process that based the request on specific and identified threats to the national security. The process would begin when the Joint Chiefs of Staff (JCS) for the Department of Defense reviewed the previous budget and identified threats to the national security of the United States projected over the next six years. Based on those identified threats, they published a document called the Defense Planning Guidance (DPG). The DPG was used by the military services to develop programs to counter those threats. Those programs were justified in a document called the Program Objective Memorandum (POM); which included all programs for a particular branch of the military. The JCS then reviewed each services POM submission for compliance with the DPG and balance between the services. When approved, this became the DoD Budget Estimate Submission (BES). At that point, DoD would then defend their budget before a joint review conducted by the Office of Management and

Budget and the Office of the Secretary of Defense. The joint review culminated with publication of Program Budget Decisions (PBDs) by the Secretary of Defense. From the DoD point of view, the budget exercise was now completed and the PBDs were forwarded to the President for inclusion in the Presidents Budget (PB) (D'Angelo, 1997: 28, 29).

The PB, composed of similar submissions from the other Federal Departments, was then further refined before being forwarded to the Senate and House of Representatives and must be submitted by 1 February of each year. The PB gave the president and the executive administration the power to propose a consistent budget that presented an economic program that included spending and taxing priorities. In addition, it also included information that was supposed to be used by all participants for the rest of the year. (Collender, 1999: 41-46).

The Budget Enactment phase would then begin in Congress with the receipt of the PB. The Congressional committees and sub-committees would met to discuss the budget proposed by the President and propose amendments of their own. Special committees within both the House and Senate then authorized the actions described within the amended budget, in essence, giving permission for the actions to take place. However, authorization did not provide the funds necessary to actually carry out the budget: A separate committee within both the house and senate performed the authorization. (Collender, 1999: 49-72]

Once the budget passed both the house and Senate, it then returned to the White House for signature by the President. Upon signature, the execution phase would begin. Funds previously budgeted by the governmental departments as amended by the Congress and the President, now would become the thirteen budget appropriations that allocated

funds back to the governmental departments. These appropriations were literally budget laws. Of the thirteen appropriations, three were of particular interest to the DoD: Department of Defense Appropriation, Military Construction (MILCON) Appropriation, and the Department of Energy and Water Development appropriation (D'Angelo, 2000: 3).

The Department of Defense Appropriation provided the majority of all military funds, including most facility M&R funds. DoD allocated the funds to the branches of the military for expense in compliance with the budget law as amended by the House and Senate and signed by the President.

The MILCON appropriation provided for large-scale military construction projects. Although large repair projects could also be funded through MILCON appropriations, the majority of MILCON funding was used for the capitalization of new facilities (D'Angelo, 2000: 3). Details of the MILCON program are beyond the scope of this research effort; however, current rules governing the program at the time of this research effort may be found in AFI 32-1021.

The Department of Energy appropriation primarily provided operating funds for the Department of Energy. However, a small portion related to military activities involving nuclear energy and nuclear weapons (D'Angelo, 2000: 3).

Typical Facilities M&R Allocation

A significant part of each service's portion of the Defense Allocation was the Operations and Maintenance (O&M) category. O&M provided the funds necessary for the normal day-to-day operations performed by the services. These costs included but

were not limited to fuel used by aircraft and ships, the wages and salaries of DoD civil servants, and facility M&R.

The Air Staff used several different methods to allocate funds to the various programs they funded. For facility M&R, the Air Staff used a percentage of the sum of the PVs of the installations within a Major Command to allocate funds to that Major Command. The rate was based on historical allocation rates and a study entitled *Renewing the Built Environment* that was published in 1989. The Air Staff established a rate of 1% of PV to provide for maintenance costs and an additional 0.75% for repair (U.S. Department of Defense, 1989: 31).

Once the Air Staff allocated funds down to the Major Command, the Major Command then re-allocated them to the installations. Most use some reference to the FIM to determine which facility repair projects to fund. However, at least one Major Command still used installation PV to determine the allocation rate to the individual installations, in essence, delegating the decision responsibility down to the leadership at each installation (Marsh, 2000).

Capitalization

In the military, new construction was primarily funded through the MILCON program, where as major repair projects may be funded through either MILCON or O&M sources, depending on funds availability. For a new mission where no facilities were available, the decision to capitalize the construction of a new facility would be warranted. For an existing mission in degraded facilities or for relocation to existing degraded facilities, the decision between demolishing the existing and constructing new was weighed against renovation of the existing structure (U.S. Air Force, 1996: 17-19).

Capitalization through renovation of the existing facility may have been an economically feasible alternative and was considered when the cost of the repairs was below 70% of the facility's value. From an economic standpoint, it may have cost substantially less to renovate a facility than to demolish the existing and build new, particularly when only a portion of the facility required renovation (U.S. Air Force, 1994c: 2). Another reason to renovate a facility rather than build new was when the facility in question had historically significant qualities or was thought to be a national treasure (U.S. Air Force, 1994b: 3). In the event that new construction was warranted, the demolition of the existing facility marked the end of that facilities useful life. The capitalization of the construction was the beginning of the life cycle for the new facility and was required to meet the needs of the organization that was to take custody of that facility (U.S. Air Force, 1994d: 5).

Summary of USAF Methodologies

The USAF used four well-defined programs to perform facility construction, maintenance, and repair. Those programs were based on the classification of work to be performed (i.e., construction, maintenance, or repair), the activity (requirements identification (RI) vs. funds allocation (FA)), and the organizational level at which the activity was to be performed (installation, MAJCOM, HQ USAF, DoD). The methodologies used in the performance of these programs were similar to those used in the non-military facility maintenance professions.

Construction -- The USAF used two programs to manage construction projects -- MC and MILCON. Neither of these programs was used for requirements identification (RI) (Marsh, 2000).

Maintenance -- The USAF used the FSM for facility maintenance projects. FSM did not identify specific maintenance requirements, however, it did estimate the expected cost of maintaining a facility over its expected lifespan, making FSM a pseudo-RI methodology. Although not planned from the outset, the USAF did allocate funds to the MAJCOMs based on FSM inputs for fiscal year 2001 making FSM a defacto funds allocation (FA) methodology (Marsh, 2000).

Repair -- The USAF used the FIM for facility repair projects. FIM was a comprehensive analysis of the condition of a facility and specified the urgency of repair requirements based on the Mission Area that facility served and the overall condition of the facility. The FIM was designed from the outset as an RI program with no plans to use it for FA (Marsh, 2000).

Table 3 graphically presents this information. A checkmark (✝) indicates the suitability of the program for M&R RI or FA. A single-asterisks (*) is used to indicate that FSM does not identify facility maintenance requirements for specific facilities, rather it identifies expected costs associated a typical facility of a given type over the projected lifespan of that facility. Similarly, a double-asterisks (**) is used to indicate that the original FIM was not designed for FA, that later iterations included provisions for FA that were optional and at the discretion of the MAJCOM BCE.

Table 3. Comparison of USAF M&R Programs

	Construction		Maintenance		Repair	
USAF Program	RI	FA	RI	FA	RI	FA
Minor Construction (MC)		X				
Military Construction (MILCON)		X				X
Facility Sustainment Metric (CAT/LCC)			*	X		
Facility Investment Metric (CAT)					X	**

Recent Advances

This research effort builds upon a thesis presented to the Faculty of the Graduate School of Engineering of the Air Force Institute of Technology in 1997 by Greggory Ottoman entitled Forecasting Methodologies for USAF Facility Maintenance and Repair Funding Requirements. In preparing Forecasting Methodologies for USAF Facility Maintenance and Repair Funding Requirements, the author extensively researched the literature available up to 1996 and documented eighteen methodologies for forecasting facility maintenance and repair funding to determine which was best suited for use by the USAF. Within these eighteen methodologies, four principle factors were identified. The eighteen methodologies were scored against the four factors with respect to their appropriate application to USAF requirements. Statistical analysis was combined with multi-criteria decision-making techniques to determine if any of the eighteen methodologies were superior for use by the USAF.

The results suggested the USAF FIM methodology was preferable to all others when the most important consideration was limiting the amount of data that must be collected and maintained. When the amount of data required for collection and maintenance was not a limiting factor, a similar program developed by the US Army Construction Engineering Research Laboratories, BUILDER, was generally found to be superior (Ottoman, 1997: 80-85).

BUILDER was an Engineered Management System (EMS) that not only predicted M&R requirements but helped facility managers make facility M&R decisions. Facility M&R requirements were predicted through a process of inventory, inspection, condition

assessment, deterioration modeling, condition prediction, and M&R planning. Each facility was reduced to it's component parts such as structural, roofing, plumbing, HVAC, etc. From this information, condition indices were developed. Condition indices were an evaluation based a scale from 0 to 100 with 0 representing failed and 100 being without visible deterioration. BUILDER included cost curves based on the condition indices that were then used to estimate future M&R costs (Ottoman, 1997: 80-85).

Since Forecasting Methodologies for USAF Facility Maintenance and Repair Funding Requirements was presented, Whitestone Research published The Whitestone Building Maintenance and Repair Cost Reference. The Whitestone Building Maintenance and Repair Cost Reference was significant because it was a comprehensive source of building M&R cost statistics focused on the total facility's expected lifespan and took into account historic inflation rates, cost variations due to geographic location, and the expected lifespan of various building components (Lufkin and Silsbee, 1999: iii).

The Whitestone Building Maintenance and Repair Cost Reference included a set of 50-year cost profiles for individual buildings. These 25 reports were produced using the Whitestone MARS® software package, were representative of common building types, and provided detailed estimates of M&R costs per square foot of floor space. Additionally, The Whitestone Building Maintenance and Repair Cost Reference included local and national cost indexes calculated for the maintenance and construction industry (Lufkin and Silsbee, 1999: iii).

Summary

This chapter provided a detailed review of the literature pertinent to this topic. Terminology needed to successfully discuss the topic was introduced and defined. The

four primary methods of determining the appropriate level of allocation of funds for M&R were next discussed in depth. This was followed by a discussion of characteristics unique to DoD when compared to non-governmental corporations.

III. Methodology

Chapter Overview

This chapter provides the methodology used to investigate the questions raised by this research effort. Specifically, how selected successful companies determine their facilities M&R requirements and how they then allocate funds to meet those identified requirements. This overall problem is broken down into three distinct questions:

- How do these companies determine the required M&R activities?
- How do these companies allocate funds to meet those identified requirements?
- How do these companies incorporate the life cycle cost and future capitalization of existing or new facilities in their overall M&R program?

First, a detailed synopsis of the case study methodology will be presented. This will be followed by an explanation of the method used to select the companies included in this research. A detailed account of the interview process will then be presented including the types of data collected and the performance measures used. Finally, the data analysis methodologies will be reviewed.

Case Study Methodology Overview

This section presents an overview of the case study methodology, which was used for the foundation of this research effort. First, the attributes of the case study methodology will be compared to the other methods available to researchers. Next, the concepts necessary for a successful case study design will be presented. This will be followed by a presentation of unique qualities necessary for data collection preparation.

Next, concepts necessary for the actual collection phase will be presented. Finally, analysis strategies will be presented.

Research Attributes

It is important to select the proper technique from the outset of a research project in order to achieve accurate and meaningful results. First, the three research aspects that form the basis of a research effort will be presented:

- Type of research question,
- Extent of control over behavioral events, and
- The degree of focus on contemporary events.

Next, the five research strategies that are based on the underlying aspects of the research will be presented:

- Experimentation
- Survey Analysis
- Archival Analysis
- Historical Analysis
- Case Study Analysis.

Finally, the specific criteria for this research effort will be explained.

Aspects of Research

The first aspect to consider is the type of research questions being asked. A categorization of these types of questions is "who", "what", "where", "how", and "why". Research that focuses on "what" typically fall into two categories: exploratory studies or outcome identification studies. Exploratory studies can actually pertain to any of the five strategies, whereas outcome identification studies generally take the form of a survey or archival analysis. Similarly, "Who" and "where" questions also favor the survey or

archival analysis. These strategies are useful for describing a prevalence being studied or when predicting an outcome. "How" and "why" questions, on the other hand, are explanatory in nature and tend to be used in case studies, histories and experiments (Yin, 1984: 18).

The second aspect to be considered is the extent of control over behavioral events. In this context, control over an event signifies the ability of the researcher to vary certain aspects of the environment while holding others relatively constant, much like a laboratory experiment. This aspect has been applied to the social sciences and is also known by the title of "social experiments." Except for experimentation, none of the strategies require behavioral control (Yin, 1984: 20).

The third aspect to be considered is the degree of focus on contemporary as opposed to historical events. Histories focus on the past, assume that no person is available with a first-hand knowledge of the facts to be examined, and rely solely on documentation and artifacts. Similar to historical research, case studies also use extensive documentation and artifacts; however, case studies also allow for direct observation and systematic interviewing, research methods usually not available to historical researchers (Yin, 1984: 19).

Research Strategies

After analyzing the research effort in light of the three research aspects, an appropriate research strategy can then be selected. Each research strategy has its own unique strengths and weaknesses, limiting their appropriateness to research questions composed of certain aspects or combinations of aspects. The five primary investigative strategies are experimentation, survey analysis, archival analysis, historical analysis, and

case study analysis. The appropriate strategy can be selected only after reviewing three separate aspects of the research to be performed (Yin, 1984: 16).

- Experimentation.
  - -- Answers the questions “how” and “why”.
  - -- Requires control over behavioral events.
  - -- Focuses on contemporary events.
- Survey Analysis.
  - -- Answers the questions “who”, “what”, “where”, “how many”, and “how much”.
  - -- Does not require control over behavioral events.
  - -- Focuses on contemporary events.
- Archival Analysis.
  - -- Answers the same questions as the Survey
  - -- Does not require control over behavioral events.
  - -- Focuses on contemporary or historical events
- Historical Analysis.
  - -- Answers the questions “how” and “why”.
  - -- Does not require control over the behavioral events.
  - -- Focuses on historical events
- Case Study Analysis.
  - -- Answers the questions “how” and “why”.
  - -- Does not require control over behavioral events
  - -- Focuses on contemporary or historical events

Specific To This Research Effort

To determine the appropriate research strategy for this research effort, recall the research questions stated in Chapter 1:

- How do companies who have earned a reputation for exceptional facility investment programs determine their M&R investment requirements?
    - -- How do these companies determine the required maintenance and repair activities?
    - -- How do these companies allocate funds to meet those identified requirements?
    - -- How do these companies incorporate the life cycle cost and future capitalization of existing or new facilities in their over all M&R program?

Each individual part of the research question focuses on "how" companies perform an activity. Therefore, an investigation strategy suited for answering "how" questions is required. Each of the five strategies available meets this requirement.

Further analysis of the research question indicates that absence of researcher influence is desirable. The purpose of the research is to document how these companies have performed the activities being researched in their natural corporate, economic, and social environment. Control over the behavioral event by the researcher in this case is neither required nor desired. Any control exerted by the researcher could taint the results and invalidated the study. This requirement eliminated the experimentation strategy since it requires hands-on control.

Finally, the research questions implied that the information required needed to be relatively current to be of value. The objective of this research was to analyze how the best companies were making those decisions at the time of the research compared to the

current USAF and DoD practices. This requirement eliminated the historical analysis strategy.

Of the remaining three strategies, the Case Study Analysis was selected as the appropriate method for this research effort. The survey strategy was eliminated on the basis that individual interviews using open-ended questions could potentially provide deeper insight to the methods used by these companies than could be provided by a survey. Similarly, the archival analysis strategy was eliminated on the basis that interviews would also yield superior information than a review of company's archived records.

Research Attributes Summary

This section presented the three research aspects that form the basis of a research effort: The form of the research question, the behavioral control requirement, and the contemporary vs. historical focus. This was followed by a presentation of the five research strategies that are based on those three underlying aspects of the research: Experimental strategy, Survey strategy, Archival strategy, Historical strategy, and Case Study strategy. Finally, the specific aspects of this research effort were analyzed to determine the appropriate research strategy for this effort with the conclusion that the Case Study strategy was best suited.

Design

This section will present the concepts necessary for designing a case study. First, the definition will be presented. Second, the four types of case study designs will be presented. Third, four aspects regarding the quality of the design of the case study will be provided. Finally, design details specific to this research effort will be presented.

Definition

A case study design is the logical sequence that connects the empirical data to a study's research questions and conclusions. In defining a case study design, Yin quoted David Nachmias and Chava Frankfort-Nachmias's definition presented in Research Methods in the Social Sciences as a plan that

> Guides the investigator in the process of collecting, analyzing, and interpreting observations. It is a logical model of proof that allows the researcher to draw inferences concerning causal relations among the variables under investigation. The research design also defines the domain of generalizability, this is, whether the obtained interpretations can be generalized to a larger population or to different situations (Yin, 1984; 29).

There are five components that are important for the design of case studies:

- A studies questions
- It's propositions
- It's unit of analysis
- The logic linking the data to the propositions
- The criteria for interpreting the findings.

The first component important for the design of cases studies is the questions, which are the focus of the research to be performed. The questions are designed to determine the research strategy. Specifically, the study questions take the form of "who", "what", "where", "how", and "why" and define the research (Yin, 1984: 30).

The second component important for the design of cases studies is the study propositions. Each proposition focuses on something that should be examined within the scope of the study. Propositions take the basic "who", "what", "where", "how", and "why" questions and narrow the scope to particular aspects that are of particular interest to the researcher. Well thought-out propositions allow the researcher to contemplate

important theoretical issues. It also directs the researchers attention towards where he or she should look for evidence relevant to the research being performed (Yin, 1984: 30).

The third component important for the design of cases studies is the unit of analysis. The definition of the unit of analysis is related to the way the research questions have been defined. For instance, if the case study is how the operational capability of a combat wing is affected by Congressionally budgeted operational funds, the primary unit of analysis would be the type of organizations to be studied (i.e. fighter wings, bomber wings, test and evaluation wings, etc.) with propositions made about how the organization is expected to behave under varying budget conditions. However, if the focus of the study is how budget cuts produce change, the unit of analysis would be the laws that produced the budget cuts (Yin, 1984: 31).

Other clarifications in the unit of analysis are also important. One important clarification is that specific time boundaries should be made clear, defining both the beginning and end of the case study. Another important clarification is consideration of any particular factor unique to geographic area of the research that may impact the results of the case study: economic conditions, religious practices, ethnicity, etc (Yin, 1984: 32-33).

The fourth component important for the design of cases studies is logic linking the data to the propositions. This can be done in many ways. One approach is referred to as "pattern-matching", where several pieces of information from the same case study are related to a theoretical proposition. This may be done by describing several potential outcomes for the initial case followed by matching the accumulated data after some treatment or change of interest takes place to the prediction (Yin, 1984: 33-35).

The fifth and final component important for the design of cases studies is the criteria for interpreting the study's findings. Currently, there is no precise standard for defining whether the contrast between patterns is sufficient to claim or eliminate a "match". If the gathered data is numerically measurable, statistical methods may be employed to determine a level of correlation. However, in most social cases, the best that can be done is to note the similarities and differences and compare to rival propositions (Yin, 1984: 35).

Types of Case Study Designs

There are four basic types of case study designs. These designs are based on whether the study is a single- or multiple case-design and whether the study has single- or multiple-units of analysis. This section will present the rationale behind the selection of single or multiple case study designs, followed by the rational for selecting a single or multiple unit of analysis design.

There are several reasons to use a single case as opposed to a multiple case design. A single case design is much like a single experiment and is appropriate used to probe for problems with a well-established theory. A single case can be used to demonstrate a unique or extreme case or document a revelatory case, one with which researchers were previously unable to study for various reasons. A drawback to the single case design is that the study sometimes turns out to be a different case than originally thought. For this reason, the researcher must take great care to ensure that misrepresentation by interviewees is avoided and that adequate access to the case study evidence is available (Yin, 1984: 42-45).

Cases that do not specifically warrant a single case design should be considered for a multiple case design. Multiple-case designs are often considered to provide evidence that is more convincing than that of a single case. However, they are also more difficult to design and implement because they require replication logic. Each case within a multiple case design must be treated not only as a single case but must each be conducted in precisely the same method to include selection of candidates, interview techniques and interview questions. The analysis phase is also complicated by the need for a rigid cross-case design and logic (Yin, 1984: 47-52).

Much like the decision between a single or multiple-case design, the researcher must also decide between the merits of a single unit of analysis and multiple units of analysis. A case where a single unit of analysis, also referred to as a holistic design, is useful is when no smaller element of analysis can be identified or reasonably used. However, the use of multiple units of analysis, also referred to as embedded design, may further focus the case study inquiry (Yin, 1984: 44-47).

Quality of the Design

The quality of the case study design can be evaluated for four particular standards. This section presents the four standards and the applicable tactics for ensuring the researcher meets those standards.

The first standard is construct validity. Construct validity is achieved when the correct measures are used for the concepts under study. Many researchers use a two-step method to ensure construct validity is achieved. Step one is to select specific measurable items that are to be studied. The second step is to demonstrate that the selected measures of these measurable items do indeed reflect the specific types of measurable items that

have been selected. There are several tactics used with case studies to achieve construct validity. One is the use of multiple sources of evidence during the data collection phase to avoid single source bias. Another is to have key informants review the draft case study report to verify that it contains the facts as they understand them.

The second standard is internal validity. Internal validity is achieved when causality, as opposed to spurious relationships, is proved in descriptive and exploratory studies. Tactics used to ensure internal validity is achieved include pattern-matching, explanation-building and time-series analysis during the data analysis phase. These tactics will be further defined in the data analysis section of this chapter.

The third standard is external validity. External validity is achieved when the study is proved to have occurred within a predefined domain and can thus be generalized beyond the immediate case. Replication logic similar to that used by scientists during experimentation is used to ensure that the researcher achieves external validity.

The fourth standard is reliability. Reliability is achieved when the various operations within the study are documented and can be repeated with the same results. The primary method of achieving reliability in case studies is to make the steps in the process regimented to the greatest degree possible.

Specific To This Research Effort

This section will present the case study design for this research effort. First, the five components important to designing case studies will be presented. Next, the type of case study will be justified. Finally, steps taken by the researcher to achieve a quality design will be presented.

Recall that the five components important to designing case studies are:

- A study's questions
- A study's propositions
- A study's unit of analysis
- The logic linking the data to the propositions
- The criteria for interpreting the findings

Analysis of this study's questions was presented previously in the Case Study Attributes section of this chapter. The questions for this study are predominantly "How" questions, which are common to all five forms of research.

For this research effort, several propositions have been developed:

1. Organizations with quality facilities maintenance programs have policies, which ensure the desired facility maintenance level is achieved.

2. Organizations with quality facilities maintenance programs place an emphasis on proactive maintenance activities to minimize repair costs and degradation of a facility prior to the end of it's designed life-span.

3. Organizations with quality facilities maintenance programs consider the impact that the facility quality will have on their employees.

4. Organizations with quality facilities maintenance programs do not lightly defer maintenance activities. Rather, maintenance is only deferred when it conflicts with a higher priority company goal. Also, organizations with high quality facilities maintenance programs are well advised of the expected results of any deferred maintenance and carefully weigh the benefits gained by the competing goal to the overall costs of the maintenance deferral.

5. Organizations with quality facilities maintenance programs have well thought out M&R requirements identification programs in place.

6. Organizations with quality facilities maintenance programs use a reasonable allocation method that links their identified facilities requirements to programmed facilities activities.

7. Organizations with quality facilities maintenance programs consider all aspects of the facility environment in their decision-making: economic, facility life span, capital investment, re-investment, etc.

The next consideration for this research effort is the unit of analysis. For this effort, the primary unit of analysis is the facilities maintenance goals and objectives set forth by the senior corporate leaders. The underlying point of view of these leaders towards their facilities and infrastructure dictates the emphasis placed on facility maintenance levels. The sub unit is therefore the various branches that make up that organization with particular interest in the branch or branches that make up the unit responsible for carrying out the corporate mandate for facilities maintenance. This sub unit can be a branch of the company, a subsidiary of the company, an outsourced facilities maintenance expert organization or some combination.

The logic linking the data to the propositions will be through "pattern-matching" in the cross case analysis. The data gathered from the companies interviewed will be analyzed and classified in light of the methodologies presented in the methodology categories section of Chapter two of this document. Corporate points of view and actions will be compared and contrasted resulting in the establishment of a level of correlation – positive, negative, or zero – between the corporate point of view and the end results of their facility maintenance efforts. Similarly, the criterion for interpreting the findings is, again, "pattern-matching".

This study is a multiple-case design with multiple units of analysis. Each corporation to be studied will be an individual case study. After completing all of the case studies, a cross case analysis will be performed to determine similarities and dissimilarities between them.

The specific point of research for this study is how the policies established by the corporate leadership related to facility maintenance influence the resulting overall

condition of the facilities. Besides documenting how these companies perform their facility maintenance identification and execution, analysis of the results will indicate whether a particular company has developed a high quality facilities maintenance program. These particular measures do assess the focus of the inquiry, thus verifying that the construction of this study is valid.

Case Study Design Summary

This section presented the concepts necessary for designing a case study. First, the definition was presented. Second, the four types of case study designs were presented. Third, the four aspects regarding the quality of the design of the case study were presented in overview format with further details to be provided in the data analysis section. Finally, the design details specific to this research effort were presented.

Data Collection Preparation

A good researcher is necessary for a case study to have good results. Although there are no tests that can be given to determine if a researcher is ideally suited for case study research, there are certain characteristics or skills that are often necessary. Additionally, there are specific preparations that must be made prior to gathering data. Those characteristics and preparations will be presented in the following sections.

Researcher Characteristics

For a case study to be successful, the researcher needs to be well-trained and experienced. In particular, a case study researcher should be able to ask good questions and interpret the answers, be a good listener, be adaptive and flexible, have a firm grasp of the issues being studied, and be unbiased by preconceived notions (Yin, 1984: 56-57).

The ability to ask good questions is an important indicator of these skills. Although the data collection follows a general plan, specific information that may become relevant during an interview cannot be predicted. A researcher who is able to ask good questions will be able to take the answer to a given question and devise further questions that probe for deeper meaning (Yin, 1984: 57).

A complement to asking good questions is the skill of listening. Listening is more than hearing an answer. It includes placing the words spoken by the interviewee into the proper context of the situation and captures the underlying mood of the interviewee from their perspective. Listening is an active rather than passive exercise where the researcher is searching not only for the directly observed meaning but also any message that may be found "between the lines (Yin, 1984: 57-58)."

Adaptiveness and flexibility are also important traits for a researcher to have. Case studies invariably require course changes during the research phase. When a change is required, the researcher must remain unbiased and take whatever steps are necessary to complete the original purpose of the case study. Often this requires repeating previously completed tasks or redesigning the entire case (Yin, 1984: 58).

Truly understanding the purpose of the case study will aid the researcher when these changes are required. Without a firm grasp of the issues, the researcher could overlook important information that indicates a course change is necessary. Conversely, the research may deviate from the true course of the study without the researcher realizing it (Yin, 1984: 59).

Lack of bias is perhaps the most important characteristic of a good researcher. A case study is useless if it is conducted in order to reinforce a preconceived notion.

Because case study researchers must be quite familiar with the topic under study, they are also prone to inadvertently introducing bias and must exercise care when gather data (Yin, 1984: 59).

Protocol

The case study protocol is perhaps the single most important document used by the researcher or researchers during the case study research. It is intended to guide the researcher through the research process and increases the overall reliability of the case study. Additionally, a protocol adds stability in the methods used for each case in a multiple case study (Yin, 1984: 64).

A protocol should have the following sections:

- An overview
- A section presenting procedures to be used in the field
- A section listing the specific questions to be used
- A section that establishes the format for the case study report.

The overview should provide the background information about the project, the issues being investigated, and the readings relevant to the issues. The overview should provide the purpose for the case study to anyone familiar with the subject matter. It should begin with a general statement about the project, it's purpose, and the people involved in the project. The major portion of the overview should present the specific issues being researched and close with a citation of readings relevant to the topic (Yin, 1984: 66-67).

The next section of the protocol details the field procedures. Field procedures can be seen as a reminder to the researcher of the specific tasks involved in collecting the data. These include:

- Gaining access to key organizations or interviewees
- Having sufficient resources and supplies while in the field
- Developing a procedure for calling for assistance and guidance if needed
- Making a clear schedule of the data collection activities
- Providing for unanticipated events (Yin, 1984: 67-70]

The core of the protocol is the questions driving the actual inquiry. These questions are to the researcher as opposed to the interviewee and are reminders of what information needs to be collected and why. They should reflect the entire range of concepts provided in the case study design (Yin, 1984: 70-72).

The final section of the protocol is the guide for the case study report. By including a guide for the report, the researcher can envision the final product while performing the research, thus making possible the collection of data in the proper format. It can also indicate the amount and detail of the documentation necessary for the report.

Protocol Development Specific To This Research Effort

The protocol for this research effort was developed following the general form outlined above and is included in Appendix 1. The overview for this case study first summarized the four basic methodologies:

- Plant Value
- Condition Assessment Techniques
- Life Cycle Cost
- Formula Budgeting

This was followed by a brief discussion of the methods used by the USAF:

- Commander's Facility Assessment

- Facility Investment Metric
- Facility Sustainment Model

Next, the project objectives were presented:

- Determine how companies determine their M&R requirements
- Evaluate how those same companies then determine the appropriate funding allocation
- Comparison with USAF practices

Case study issues were next addressed. The first issue presented was defining the term "exceptional facility investment program" as a formal program that develops a strategy for facility maintenance that balances the cost of maintenance with the benefits, both tangible and intangible, those facilities provide. The second issue presented was how companies were to be selected for the research. The final topic presented by the overview was a list of publicly available documents relevant to the topic.

The second section of the protocol was titled Field Procedures, which outlined how the actual field research would be performed. This section listed the various credentials and access needed by the researcher, listed general sources of information, and provided general procedural reminders.

The third section of the protocol was entitled Case Study Questions. This section listed the open-ended questions to be used during the interview phase:

Topic 1: Maintenance Requirements Identification

1. Do you have any documentation that illustrates how your company is organized and how the facility maintenance section fits into that organizational structure that I may take with me?
2. Can you explain to me how your organization determines the maintenance requirements for your facilities?

3. Can you explain to me what goals your company decision makers had in mind when setting up this method of determining maintenance requirements?

4. What other methods has your company tried prior to implementing this method for determine the maintenance requirements for your facilities?

5. Can you explain to me how your company differentiates between restoration (i.e., repair) and sustainment (i.e., maintenance) requirements?

6. What level of in-house maintenance capability does your organization have and what role do they play?

Topic 2: Maintenance Funds Allocation Methods

1. How does your organization determine the amount of funds to be allocated for the maintenance requirements identified?

2. How does your organization allocate funds?

3. Does your company take into account the re-capitalization rate (i.e., length of time required to replace existing facilities at the current rate of investment) of your plant infrastructure when deciding an appropriate allocation rate?

4. How do your customers (i.e., senior management, internal employees, and non-employee visitors) feel about the level of quality to which you maintain your facilities?

    4.1. Have any comments been made concerning the acceptableness of the environment you maintain?

    4.2. Can you explain to me any formal or informal methods for customer feedback that you have in place?

    4.3. What impact does the perception of the facility condition by the employees working in that facility have on your allocation rate?

These two sections – Field Procedures and Case Study Questions – are important because they provide the stability necessary for performing identical case studies for each corporation.

The final section of the protocol was titled Analysis Plan. This section presented the data analysis strategy to be used for each case and defined the form that the case study report would take. A copy of the case study protocol for this research effort is provided in Appendix 1.

Candidate Selection

This section presents the methodology used to select candidate companies for this research effort. First, the method used to develop a pool of candidate companies is outlined, followed by the methods used to reduce this pool to a manageable number of companies to be interviewed.

The purpose of the candidate selection process was to choose companies that had established a minimum level of facility quality, developed methods to determine their facility maintenance and repair requirements, and developed methods to allocate funds to meet those identified requirements. Additionally, companies that maintained their facilities in excellent condition for the type of work performed were desirable. The selection process was a multi-phase activity. The first phase was to develop a large pool of companies that might have facilities maintenance programs that met the above criteria in place for further investigation. Utilizing the expertise of several knowledgeable sources carried out this phase of the process.

The first source was USAF facility maintenance professionals. Over the years, several companies have become known to USAF facility maintenance professionals as having excellent facilities. Although maintaining facilities at a high quality level does not equate to having an excellent facility maintenance program, because the company did have excellent facilities and remained competitive in their market suggested that further

investigation was warranted. In particular, staff members from both HQ USAF/ILEP and HQ AFMC/CEP provided several companies to consider. These suggested companies were used to create a list for further investigation.

Facility maintenance professional societies were the second source of candidate companies. The International Facility Management Association (IFMA), the Association for Facilities Engineering (AFE), the Building Owners and Managers Association (BOMA), and the Society of American Military Engineers (SAME) were contacted for lists of companies that were recognized by their peers as having excellent facility maintenance programs. These companies were then added to the list of candidate companies selected for further investigation.

The third source was the Fortune Magazine list of the 500 wealthiest public held companies, commonly referred to as "The Fortune 500." These companies were analyzed because they are profitable and have shown the ability to compete within their particular niche successfully. Market success alone does not indicate a company has an excellent facility maintenance program; however, many companies today include work environment as part of the total employee compensation plan (Useem, 2000: 98). The operation of facilities is typically capital intense. Arguably, facilities operation information gathered from companies that are competing successfully may provide insight to the types of programs that contribute to the overall success of the company.

These three sources provided a large pool of companies with the potential of having quality facility maintenance programs. A method was devised to reduce the pool to a smaller and more manageable number of candidates. This reduction was done by initially analyzing each company for similarities and differences with the USAF and

selecting those companies that appeared to have a relevant correlation with some aspect of USAF operations narrowed the field down.

Although no single criterion was used to eliminate companies, several specific traits were of interest. One trait of particular interest was the physical dispersion of a particular companies facilities. The USAF has installations located across the continental United States, Alaska, Hawaii, and various foreign counties. Therefore, companies with dispersed facilities may have many of the same complexities of management as the USAF.

Another trait of interest was the technological expertise needed by employees. The USAF is composed of highly skilled people operating and maintaining sophisticated aircraft and missile systems. Ever more often, companies that are competing for skilled and talented employees are investing in quality facilities in order to remain competitive in their market niche. Companies that do not meet the employees' expectations, including the quality of life of the employee in the workplace, often find that they cannot remain competitive within the marketplace due to the defection of their best employees to companies that meet or exceed the expectations of those employees (Useem, 2000: 2] (U.S. General Accounting Office, 1999: 17).

This exercise reduced the pool to 44 companies (Appendix 2), which was still excessive for the scope of this research effort. However, each company remaining in this reduced pool was considered to be an ideal candidate. The initial companies selected were those that were both located physically near Wright-Patterson AFB, Ohio, and interested in participating in this research. A pool of companies with a probability of having excellent facilities maintenance programs that are also similar to the USAF in terms of

size, plant dispersion, and technological requirements resulted from this selection process. Those companies were:

Daimler-Chrysler, Jeep Division, Toledo, Ohio

Dana Corporation, Toledo, Ohio

General Motors, Moraine Assembly, Dayton, Ohio

Mead Corporation, Dayton, Ohio

NCR Corporation, Dayton, Ohio

It should be noted that these companies were not considered to have exceptional facility investment programs at this point in the research; rather, that they displayed characteristics that indicated they might have an exceptional facility investment program and, therefore, further research was warranted. Analysis of the selected companies' policies and practices were then compared with the definition used in chapter 2 to determine if they actually met the criteria.

Data Collection

This section will present the two primary aspects that a researcher must keep in mind while performing the data collection phase of a case study: sources of evidence and data collection principles. First, the six sources of evidence will be presented. This will be followed by a presentation of the three principles important to any data collection effort. Finally, data collection details specific to this research effort will be presented.

Six Sources For Data

There are six sources for the collection of data:

- Documentation
- Archival records
- Interviews

- Direct observations
- Participant-observations
- Physical artifacts

Documentation and archival records each provide solid evidence that can be used to support the research conclusions. Interviews are important sources of information in case studies and there are several types of interview techniques. The first type of interview requires the use of open-ended questions, which allows the subject to elaborate. A second type of interview is a focused interview where a respondent is interviewed for a set period of time. A third type of interview is more structured and is more along the lines of a survey (Yin, 1984: 78-85).

Direct- and Participant-observations are the next two forms of data gathering. Both of these forms allow the researcher to make direct observations of the processes under study. The difference between the two is that direct observations have little to no interaction between the researcher and the process. Participant-observations allow the researcher to participate in the study. A drawback to the participant-observation form is the potential for bias (Yin, 1984: 86-87).

The sixth data-gathering source is physical artifacts. Physical artifacts are physical objects that can be collected during the research. They are extensively used in anthropological research but may have uses in other studies as well (Yin, 1984: 88-89).

Three Principles of Data Collection

There are three principles of data collection. The first principle is to use multiple sources of evidence. The use of multiple sources allows for increased breadth of study and increases the reliability of the data gathered. Since the multiple sources may provide the same evidence, the construction of the research is further validated (Yin, 1984: 90).

The second principle of data collection is to create a case study database. A case study database consists of the case study notes, documents, narratives, and tabular data gathered during the research effort. The case study database is then used to compose the case study report and ensures consistency between the raw data and the published findings (Yin, 1984: 95-96).

The third principle of data collection is to maintain a chain of evidence. This technique allows an observer to follow the chain of reasoning from the initial research question through to the final conclusions. When followed, this principle increases the reliability of the study (Yin, 1984: 96]

Specific To This Research Effort

Data collection was carried out using documentation, archival records, and interviews, as set forth in the case study protocol. Prior to the interview, a copy of the case study protocol was sent to the company representative. A copy of the case study protocol is included in Appendix 1.

Each interview followed the questions included in the protocol, allowing the company representative opportunity to elaborate on the methods used by their company to perform the specific tasks outlined in the question. Each interview was tape recorded and transcribed for later analysis. A copy of the interview transcripts are included in Appendix 3.

To the greatest extent possible, multiple sources were used. These sources included interviews with the facility maintenance supervisors, documentation from their company, personal observations by the researcher, and published records. A database was created to maintain the evidence collected. This database includes the physical

documentation gathered at each interview, the tapes and transcriptions of the interviews, and any other pertinent documentation collected during the research phase. These items in the database are be presented in Chapter 4 so an observer will see the chain of evidence clearly.

Analysis

This section will present the general analytic strategy for analyzing the case study. First, general strategies will be explained. Next, modes of analysis will be presented. Finally, data analysis details specific to this research effort will be presented.

General Strategies

Analysis is the most difficult phase of a case study because few formulas have been developed. Logical thought and an adequate line of reasoning by the researcher must make up for this shortcoming. However, there are two general strategies that may be helpful to the case study researcher, aiding him or her in treating the data impartially, producing convincing conclusions, and ruling out other interpretations (Yin, 1984: 100).

The first strategy is to rely on theoretical propositions. The reasoning behind the strategy is that the theoretical propositions shape the data collection plan, which then give priorities to the relevant analytic strategies. This method focuses the researcher's attention on the important data, helps to organize the entire case study, and defines alternative explanations to be explored. Analyzing the causal relationships in this way can be very useful in guiding the overall case study analysis (Yin, 1984: 100-101).

A second strategy is to develop an explanatory outline for organizing the case study and is useful when theoretical propositions are not available. This outline may take

the form of a table of contents that lays out a book in a logical, descriptive order (Yin, 1984: 101-102).

Dominant and Lesser Modes of Analysis

This section presents several modes of analysis. First the three dominant modes of analysis are presented: pattern-matching, explanation-building, and time-series analysis. Following this, the three lesser modes of analysis are presented: embedded units, making repeated observations, and the case survey approach.

The first dominant mode of analysis is pattern-matching. This logic behind this method is to determine if the observed results correlate with one that was predicted. If the patterns do in fact match, the results can strengthen the internal validity of the case study design. Pattern-matching requires no precise comparisons such as statistical correlation and variance. Rather, a general match of the stated patterns is sought. This is considered to be the major drawback of this technique: it allows what is perceived as excessive latitude in the researchers interpretation of the results. To overcome this potential problem, researchers often seek case studies in which the outcomes are likely to lead to gross matches or mismatches, thus avoiding the likelihood of researcher bias (Yin, 1984: 103-107).

The second dominant mode of analysis is explanation-building, which is a special case of pattern-matching. Explanation-building is mainly relevant to explanatory case studies. It is also considered to be more difficult than simple pattern-matching because it seeks to explain complex concepts that are difficult to measure in any precise manner. For this reason, explanation-building often takes the form of a narrative. Another drawback is that explanation-building often requires a large amount of iterative work where an

explanation is presented, analyzed, refined, analyzed again and so forth, gradually refining the explanation over time. (Yin, 1984: 107-109).

The third dominant mode of analysis is time-series analysis. Time-series analysis seeks to document patterns over a period of time to explain the how and why of the particular phenomena under study (Yin, 1984: 109-114).

The first lesser mode of analysis is the analysis of embedded units. An embedded unit of analysis occurs when significant sub-units of data are available for a specific unit of analysis. This is often the case when multiple case studies are performed. The multiple case study uses each case as a unit of analysis; however, each case has sub-units within it. These sub-units are considered to be the embedded units of analysis. They cannot be the sole analytic technique but must be augmenting one of the dominant modes of analysis (Yin, 1984: 115-116).

The second lesser mode of analysis is making repeated observations. When observations are repeated over time, they form a type of time-series analysis. Observations can also be made simultaneously at several sites (Yin, 1984: 116).

The third lesser mode of analysis is referred to as the case survey approach and is an approximation of the cross case analysis. This method relies on a “coder” to review the data and prepare what is essentially a survey based on the answers to each case. The data is then tallied and analyzed much in the way of a typical survey. This is considered to be a secondary analysis technique and therefore is unlikely to achieve either theoretical or statistical generalizations. However, the technique may be relevant when the research objective doesn’t require primary data analysis.

Specific To This Research Effort

This research was a descriptive case study and the data analysis technique was designed around that premise. Analysis was performed in two stages. The first stage was an analysis of each individual case and the second stage was a cross case analysis.

The first stage was broken down into three phases. The first phase was to present a description of the company. This description consisted of the historical roots of the company, major changes in the company's product line, physical traits such as the company's size and facility locations, and facts concerning the particular plant visited.

The second phase compared the five points of analysis with the performance of the company. Those five points were:

- Determine the company's maintenance requirements identification methods
- Determine the company's funding allocation method
- Analysis of how the company's requirements identification phase worked with their fund allocation phase
- Determine the company's view of restoration vs. sustainment
- Determine the company's view of life cycle costs and capitalization

The third phase used pattern-matching and explanation-building to compare the results with those predicted by the case propositions.

The second stage was a cross case analysis of the multiple case study. The cross case analysis compared the methodologies of the companies studied and presented findings of commonality and/or differentiation between them. Methods and techniques that contribute to any companies' results were noted. The techniques used were then compared and contrasted with the methods used by the USAF.

Summary

This chapter provided the methodology used to research how companies who have earned a reputation for exceptional facility investment programs determined their M&R investment requirements. First, a detailed synopsis of the case study methodology was presented, followed by an explanation of the method used to select the companies that were included in this research. A detailed account of the interview process was presented including the types of data collected and the performance measures used. Finally, the data analysis methodology was reviewed. This sets the stage for the next chapter where the actual case study data will be presented and analyzed.

IV. Research Results

Chapter Overview

This chapter presents the results of the research and analysis with regard to the research questions presented in chapter 1:

- How did successful companies determine their facilities M&R requirements and how did they then allocate funds to meet those identified requirements:
  - -- How did these companies determine their maintenance requirements?
  - -- How did these companies allocate funds to meet the requirements that have been identified?
  - -- How did these companies incorporate life cycle costs and capitalization into their overall M&R strategy?

This chapter presents the analysis of the individual case studies, followed by a cross case analysis, and concludes with additional insights and a chapter summary.

In addition to the five companies presented in this chapter, an additional company was originally elicited for inclusion in this study. At the time of this research effort, Pyramid Services was the contracted facility maintenance provider for maintenance and repair efforts at several aircraft production facilities. Early discussions with the contract monitor indicated that the aircraft company responsible for the aircraft production was also responsible for maintenance and repair of the facility and had contracted with Pyramid Services for that work. Subsequent investigation revealed that the contract was actually between Pyramid Services and the USAF. Further research into the practices of Pyramid Services was not warranted as they performed their duties as directed by the

contract between them and the USAF with oversight from an Air Force Contracting Officer.

Case Study Analysis

This section presents the results of the individual case studies. The cases are presented in the alphabetical order and do not reflect in any way the quality of the company nor their established facility M&R programs. Analysis is based predominantly on interviews held with knowledgeable company representatives, although corporate documents and published company information is also included. Transcripts of the interviews are in Appendix 3.

Daimler-Chrysler Toledo North Assembly Plant

Background

Present-day Daimler-Chrysler AG is the result of the combination of several automobile companies over a 117-year period of time. The three major companies were Benz & Co., Daimler, and Chrysler Corporation. The "Benz & Co. Rheinische Gasmotoren-Fabrik, Mannheim" was initially founded in 1883. The company developed gasoline powered engines for use in automobiles and, later, aircraft (Daimler-Chrysler AG, 2001: n. pag.). The second company of the three began in 1866 with the manufacture of the first Daimler engine powered carriage. Like Benz, Daimler also focused on manufacturing automobiles and engines for aircraft. Daimler applied for trademark protection of what would come to be the world’s most well known name, Mercédès, in 1902 (Daimler-Chrysler AG, 2001: n. pag.).

Daimler and Benz merged as Daimler-Benz AG in 1926. Daimler-Benz was at the forefront of automotive design, building the prototype for the Volkswagen in 1937,

developing the occupant safety cell in 1951, a scientific crash test program in 1959, and successfully competing in automotive racing events worldwide. Daimler-Benz established its presence in the North American car market in 1952. In addition to automobile manufacturing, Daimler-Benz also manufactured heavy commercial trucks and engines for ships, trains, and aircraft (Daimler-Chrysler AG, 2001: n. pag.).

The Chrysler Corporation is the third company that makes up the present day Daimler-Chrysler AG. Walter P. Chrysler began his automotive career with General Motors but left to form his own company after a fall out with GMs chief executive officer, William Durant. The Chrysler Corporation was founded in 1924 and quickly grew, acquiring the Maxwell Motor Company in 1925 and Dodge Brothers Incorporated in 1928. The Chrysler Corporation set automotive standards with the introduction of safety glass in 1933, aerodynamic design in 1934, and other innovations through the years. Chrysler acquired the Jeep brand name with the purchase of the American Motors Corporation in 1987 (Daimler-Chrysler AG, 2001: n. pag.).

Daimler-Benz and Chrysler agreed to combine their businesses in a "merger of equals" in 1997. The result is Daimler-Chrysler AG, a global company, which produced two million automobiles (Mercedes-Benz, smart®, Chrysler, Dodge, Jeep) and 549,000 commercial vehicles (Mercedes-Benz, Freightliner, Sterling, Setra and Thomas Built Buses) in 2000. (Note: smart® is a new brand name for a micro-compact car specifically designed for personal transportations needs found in high-density urban areas such as Paris, London, and Tokyo.) Additionally, Daimler-Chrysler AG produces automotive electronics for industrial diesel, gasoline, and gas turbine engines for commercial trucks, ships, aircraft and railroad locomotives (Daimler-Chrysler AG, 2000: 3-34).

Daimler-Chrysler began construction of a modern assembly plant, the Toledo North Assembly Plant (TNAP) in the fall of 1999 to replace the aging Toledo Assembly Plant (TAP). The facility was completed within 12 months and has approximately 1200 square meters of floor space. After completion of the facility, an additional year was required to install the specialized equipment necessary for vehicle assembly. Vehicle production began in January 2001. TNAP employs approximately 2100 employees, 321 of which are equipment and facility maintenance workers (Roberts, 2001: 29).

Overall, the condition of the facility was good. The design and construction of the facility appeared to have focused on providing a modern, no-frills automobile assembly plant. The work areas, both on the production deck and in the administrative areas, were well lighted and comfortable. The production equipment had been located to maximize production efficiency. Being a new facility, the effects of maintenance deferral was not yet obvious.

Before constructing TNAP, Daimler-Chrysler commissioned a group of over 40 skilled tradesmen to benchmark the best practices in use both within and outside of the automotive industry. This group was not limited to specific areas of improvement; rather, they were encouraged to examine any practice that could be applied to automotive manufacturing including production methods, facility design, use of robotics, etc. Additionally, this group looked at other enterprises that operate in an assembly line process, including airlines, racing pit crews, and aircraft carrier operations. The ultimate goal was to document processes that worked well and apply them to the automobile assembly line that was being designed at that time (Roberts, 2001: 1).

The benchmarking group used a two-step process to accomplish their goal. The first step was a brainstorming session where each member was encouraged to suggest any ideas relevant to the improvement of the automotive assembly process. The ideas generated ranged from simple process improvements to in-depth research of how companies with similar process requirements performed their tasks. These ideas and suggestions were then collated into groupings of similar concepts (Roberts, 2001: 1-3).

The second step was the investigation of the ideas. Each of the group members became the "champion" for a particular idea or suggestion to be investigated and was given the latitude necessary to perform their research. Members of each trade worked together during the research phase to share their own expertise and to address each requirement from the unique point of view resulting from their specialized backgrounds and experiences (Roberts, 2001: 1-3).

In addition to best practices, maintainability of equipment was strongly emphasized during the construction of the TNAP. The maintenance history of particular machines supplied from specific vendors was derived from their own experiences as well as those of maintenance workers at other D-C assembly plants. The group members then reviewed the equipment specifications and disqualified equipment with a record for maintenance problems (Roberts, 2001: 6, 15).

Daimler-Chrysler also required equipment suppliers to use standardized or common parts to minimize bench stock costs for the new facility. An example of this is in the selection of the drive motors for the conveyor lines. Originally, three different sized drives were specified. However, increasing the size of the smaller drives to match the largest drive permitted them to reduce the number of spare drives in bench stock from

three to one. Although this increased the cost of the initial procurement, the savings incurred from stocking one spare drive common to all lines rather than three unique drives actually reduced the total cost (Roberts, 2001: 6-7).

Descriptive Case Results

TNAP currently has no dedicated facility maintenance personnel; rather, the equipment maintenance personnel address facility maintenance requirements. When a facility problem is reported, a maintenance worker is dispatched to investigate it. If the problem is relatively straightforward and does not interfere with assembly line equipment maintenance, the in-house maintenance technicians will fix it. Otherwise, a contractor is brought in (Roberts, 2001: 13).

M&R Requirements Identification

Maintenance requirements identification for TNAP may be classified as a LCC method and the methodology was developed from several sources. The primary source for equipment maintenance requirements was the equipment manufacturers recommendations. Each piece of equipment installed at the plant came with recommended intervals for certain maintenance activities, such as weekly filter changes. Additionally, the experience of the technicians in maintaining the equipment was also considered and used to either increase or decrease the maintenance intervals (Roberts, 2001: 30, 39-40).

These identified maintenance requirements were then compiled in a computer-based preventive maintenance program that determines the number of people that are necessary to carry out the identified requirements. This program also scheduled the

maintenance and generated report, which assigned each requirement to an individual maintenance technician (Roberts, 2001: 14).

Maintenance was addressed in this manner at TNAP because the facility and equipment were new. However, a balance between the cost of the maintenance requirement and the benefit received from the maintenance activities were also pursued. Maintenance is not performed just because it is "required" by the manufacturer but rather to ensure the life expectancy of the equipment and facility exceed the expected requirement. Maintenance levels recommended by the equipment manufacturer may ensure that the equipment item can function indefinitely; however, if the expected need for that equipment item is ten years, only the maintenance necessary to meet that lifespan is performed (Roberts, 2001: 39-40).

The repair requirements identification process may be considered a CAT methodology. TNAP has implemented no formal method for identifying facility repair requirements. Instead, TNAP facility maintenance personnel rely primarily on the equipment operators, assembly technicians, skilled tradesmen, or equipment maintainers to notify them when a problem in noted. Facility inspection of an area where a new piece of equipment is to be installed is considered part of the equipment installation procedure (Roberts, 2001: 17, 32).

In addition to user notification, TNAP has several indirect methods for identifying requirements. One is the use of equipment monitoring devices that track energy consumption on a daily basis. Over the course of time, this data can be reviewed to locate equipment items, such as air handlers, that are drawing excessive electrical current. Those

devices can then be inspected to determine the cause of increased load and repaired if necessary (Roberts, 2001: 31-32).

Another indirect method is through annual OSHA/EPA audits. Each year, a team of corporate inspectors audits the plant. These inspectors are primarily looking for safety or EPA violations. During the inspection, facility problems may be discovered, which are then reported to the facility manager (Roberts, 2001: 45).

Minor repairs are performed as needed and as directed by the facility manager. When major repairs are required, they must first be justified to DC corporate headquarters. The primary method of justification is detailed documentation. This documentation typically includes photographs of both the facility need (i.e. failed roof) and the impact to plant production (i.e. water damage to vehicles due to failed roof). The overall cost of the problem is estimated and includes the above costs plus cost for reworked product, loss of man-hours, etc. Urgent problems are immediately addressed to corporate. Less urgent repairs are included in the annual budget submission. (Roberts, 2001: 33-34]

Due to the emphasis on vehicle production, deferral of facility maintenance and repair requirements is almost a given. Facility requirements are analyzed with respect to impact to production. Requirements that impact production, such as a roof leak over the assembly line, are addressed quickly, while less critical requirements, such as re-lamping light fixtures in administrative areas, are deferred. Historical data gathered from Jefferson Street Assembly Plant (JSAP), a plant similar to TNAP that was constructed within the last decade, indicates that deferring non-critical facility maintenance will eventually require a full-time facility repair crew within five years. The backlog of requirements at

JSAP justified the addition of eight permanent workers whose only task was to address deferred facility maintenance requirements (Roberts, 2001: 14, 44).

M&R Fund Allocation

The primary factor for allocating facility M&R funds is the annual capital plan and may be categorized as a CAT methodology. The annual capital plan includes all costs for the plant. Facility related line items include facility maintenance requirements, any expected or planned repair projects, and facility construction projects.

Scheduled maintenance costs for the TNAP are estimated based on the expected workload and include both material and labor costs. Material costs are based on the equipment manufacturers recommendations (i.e. change filter once a week times cost of filter). Similarly, the labor costs are estimated from the expected time to perform scheduled activities times the hourly pay rate. These costs are annual recurring costs and are updated each year (Roberts, 2001: 33).

With the exception of emergency or urgently needed repair requirements, allocation for facility repairs is included in the annual capital plan. These costs are gathered from all of the requirements identified during the previous year and must be accompanied with detailed justifications. Repair costs are typically non-recurring, single year requirements (Roberts, 2001: 33).

Emergency or urgently needed repair requirements are addressed outside of the annual capital planning process. Once identified and documented, the requirement is forwarded to the corporate headquarters for review. Funds are then acquired by shifting funds from another plant to the more urgent requirement, reprogramming the funds

previously allocated to the plant by deferring other planned repairs, or allocating additional funds (Roberts, 2001: 33).

Another factor in funds allocation is the availability of funds within the corporation. Overall operating expenditures are predicted for the year as well as projected vehicle sales and profit. Shareholders then will decide what amount of capital will be available that year. In response to that, DC corporate comptroller reviews the project justifications and awards funds to those repair projects that best meet the corporate needs, not to exceed the total amount available. (Roberts, 2001: 46-47).

Requirements/Allocation Integration

Facility M&R fund allocation is based on two criteria. The first criterion is a fully justified facility requirement. Identified requirements are included in a project that is fully described and justified as outlined above. Responsible members of the local staff, including structural engineers, environmental specialists, safety specialists and the local comptroller review the proposed project in view of their specialties. The project is then forwarded to DC corporate headquarters where it is again reviewed, this time from a corporate wide perspective (Roberts, 2001: 34-36).

The second criterion is the amount of capital available for the requested work. As a publicly held corporation, DC shareholders determine what the operating budget will be each year. That operating budget is based on expected operating expenditures, profit margins, industry economic projections, and the needs of other plants within the corporation (Roberts, 2001: 46-47).

Capitalization

The choice between capitalizing the construction of a new facility and capitalizing the repair of an existing facility is a complex economic decision. Daimler Chrysler's decision to build TNAP is a perfect example. Daimler Chrysler knew that a new product was desired for the Sport Utility Vehicle (SUV) market. The vehicle, known as the Liberty™, was proposed to replace the entry-level Cherokee™, which is currently produced at the TAP (Roberts, 2001: 35-37).

The primary reasons for building the TNAP were purely economic. Vehicle production at TAP was costly due to the age and condition of the facility. The original buildings at TAP were constructed prior to WW I and have continually been added on to over the decades. The currently existing campus is a collection of multi-story factory buildings. These facilities were considered to be inefficient due to the technologies used during their construction, in particular, heating, cooling, and ventilation costs were significantly higher than that of a modern facility. Additionally, there is an increased cost of producing vehicles in multi-story facilities due to increased material handling requirements such as elevators and conveyors as well as increased equipment maintenance costs inherent in multi-story assembly lines (Roberts, 2001: 35-37).

Another consideration was the high cost of renovating the existing facility in comparison to constructing a new facility. In order to renovate the facility, careful and costly demolition by hand using due care would have been required to prevent unnecessary damage to the facility and equipment that was to remain. In comparison, razing the old facility would be a relatively inexpensive activity. Constructing the new

plant cost approximately $625 per square meter ($58 per square foot), significantly less than the expected cost of renovating the existing facility (Roberts, 2001: 35-37).

A third consideration was the lost revenue incurred by the division during the platform change. The Liberty is a larger vehicle than was previously manufactured at the TAP and required new paint and corrosion prevention systems. These paint and corrosion prevention systems were large and could not be manufactured and delivered to the site; rather, the individual component pieces were manufactured off site, and shipped to the plant for final assembly. They were also complex and required up to a full year to complete installation, whether in an existing facility or a new assembly plant. If they were to be installed in the existing plant, vehicle production would have been forced to cease until the conversion was completed, thus incurring an additional loss of revenue (Roberts, 2001: 35-37).

These costs and others were calculated and used as part of the economic analysis. The result was a decision to continue operating the TAP while the TNAP was under construction and to demolish TAP after TNAP was in full production and the product at TAP was phased out of their product lineup (Roberts, 2001: 35-37).

Table 4 presents the methods used by Daimler-Chrysler Corporation to identify facility requirements and allocate funds for construction, maintenance, and repair activities. The facility managers identify construction requirements by specific need for new construction and condition assessment for existing facilities. Maintenance requirements were identified by a combination of LCC and CAT methodologies. LCC was used to prepare an initial maintenance program and the condition of the equipment or facility was taken into consideration as it aged. Repair requirements were identified by an

assessment of the facilities condition. For each of the three activities, funds were allocated based on the identified requirement.

Table 4. Requirements vs Allocation for Daimler-Chrysler Corporation

	Requirement Identification	Funds Allocation
Construction	Need/CAT	RI
Maintenance	LCC/CAT	RI
Repair	CAT	RI

Facility Maintenance Program Overall Impression

Daimler-Chrysler AG's M&R program as implemented at TNAP did not meet all of the five criteria established for classification as an exceptional facility maintenance program.

Determine a desired level of facility quality.

TNAP maintenance personnel have established a desired level of facility quality, based on the minimum standard dictated from Daimler-Chrysler AG corporate offices.

Adopted a method to determine the facility M&R requirements.

TNAP facility maintenance personnel went to great lengths to establish maintenance requirements for production equipment. Although carrying less emphasis, detailed facility maintenance requirements were included in that effort. However, TNAP facility maintenance personnel have no established repair identification method in place. Repair requirement identification relies on notification by an observant factory worker or discovery by facility maintenance personnel during safety inspections or equipment installation.

Developed a method to allocate funds to meet those identified requirements.

TNAP maintenance personnel include all maintenance related requirements in their annual budget. Minor repairs are funded from the plants annual operational funding. Substantial repair requirements are extensively documented and forwarded to their corporate headquarters for review and funding.

Take into account the eventual need for capitalization in the facility life cycle.

Capitalization requirements were addressed from a business decision point of view. TAP and TNAP are perfect examples of the corporations facility condition analysis and decision making process.

Maintain facilities in excellent condition for type of work performed.

The condition of TNAP at the time of this research effort provided excellent working conditions for the assembly of automobiles. However, the planned practice of facility maintenance deferral was expected to lead to a degraded facility condition requiring a crew to be put in place to address the backlog of facility maintenance and repair requirements. Inevitably, this backlog could contribute to increased equipment down time and negatively impact productivity.

Dana Corporation

Background

Dana Corporation traced it's heritage back to 1902 when Clarence Spicer, then a student at Cornell's Sibley College, invented the universal joint for use in automotive power transmission. Universal joints eliminated the need for sprocket and chain drive systems, which were significantly less dependable, more maintenance intensive, and inherently dangerous. Clarence Spicer received a patent for the universal joint in 1903

and began manufacturing them the following year. Demand for the universal joint was very high and quickly outpaced Spicer's production capacity. In 1914, an investor named Charles Dana provided the necessary capital to expand Spicer's operation to meet the demand. Over the years, Dana continued to expand and acquired other automotive product manufacturing companies including the Indiana Piston Ring Company, the Victor Gasket Company, the Wix Company, the NAPA Auto Parts distribution chain and several related companies in Europe (Dana Corporation, 2001: n. pag.).

At the time of this research effort, Dana Corporation was one of the world's largest suppliers of components, modules and complete systems to global vehicle manufacturers and their related aftermarket. Based in Toledo, Ohio, the company operated some 300 major facilities in 35 countries and employed more than 75,000 people (Dana Corporation, 2001: n. pag.).

Dana Corporation's headquarters campus consists of five buildings located on 178.8 acres. Of the five buildings on this site, two of them were large administrative offices totaling approximately 176,000 square feet of office space. The main building was constructed in 1969 and modeled after the colonial governor's mansion at Williamsburg, Virginia. The second administrative facility was constructed in 1985 and architecturally matches the original structure. Also, there was a separate 28,000 square foot facility for facility maintenance crew offices, shops, and equipment storage. The remaining two facilities were guesthouses, used by visiting dignitaries and guests of the Dana board of directors (Dennis, 2001: 1).

Rare among today's corporate practices of focusing on corporate core competencies was Dana's use of a dedicated, in-house facility maintenance crew. When

questioned about this, a company spokesman stated that one of the company's goals was to project an image to company employees, corporate visitors, and the community that Dana Corporation was a superior company. Part of that goal was met through providing superior facilities. Dana corporate leadership believed that maintaining a dedicated, in-house workforce with corporate *esprit de corps* would better achieve these desired results than an outside contractor with little more than a contractual obligation to meet the negotiated requirements.

The facility condition of the Dana Corporation headquarters suggested that the effort is working effectively. Although the reduction in facility maintenance activities due to current economic conditions within the automotive industry had been recently implemented, the entire facility was immaculately well maintained. The administrative areas were comfortable, well lighted, tastefully decorated, and presented no visible detractors. The facility looked as if it they had moved in yesterday while, in reality, it was over 30 years old.

Descriptive Case Results

Dana Corporation's corporate structure was divided into seven business units, each responsible for their individual profitability with guidance provided from the corporate office. Typically, five layers of management separated the CEO from a production employee. Facility maintenance was left up to the individual product division, with oversight from Dana Corporate Headquarters. Guidance from Dana Corporation's headquarters took the form of dictating a minimum acceptable level of facility condition:

> We want to portray an image to our customers and to the communities that we are a top-notch organization. We understand that the image people have of us today is the reputation that we will have tomorrow. We always want that to be a positive image (Dennis, 2001: 1-2).

This emphasis on projecting an image of excellence was given as one of the reason for maintaining a superior facility condition level and contributed to what they referred to as the "Wow factor." This image was portrayed from the moment a visitor entered the campus. A wrought-iron and brick fence protected the perimeter. The winding drive passed manicured flowerbeds, well-groomed lawns and shrubs. The formal walkway to the colonial-styled facility's main entrance was a wide expanse of red brick-pavers.

Once inside the facility, every detail again contributed to the subjective impression that Dana Corporation was an excellent company. Offices were well laid out and used high-grade furnishings that appeared to be in excellent if not new condition. Surface finishes, such as carpets, ceilings, and walls, were all in like-new condition. Similarly, the mechanical systems and other "hidden" equipment appeared to be similarly well-maintained.

These observations were made at the HQ facility in Toledo, Ohio. The interview and subsequent conversations indicated that similar emphasis on exceptional facility maintenance levels were the rule rather than the exception across the corporation.

M&R Requirements Identification

Dana Corporation's corporate office used a combination of the LCC and CAT methods for their M&R identification program. Dana did not differentiate between facility maintenance and repair. Their facility M&R goals were to 1) provide a comfortable facility to maximize productivity of employees, 2) minimize the impact of facility related maintenance and repair on the employees, 3) provide an impressive facility that is reflective of the quality standards their company adheres to (Dennis, 2001: 1, 5-7, 20).

Dana Corporation used manufacturers recommendations to build a preventive maintenance routine, which was rigorously adhered to. Over time, their historical records plus in-house experience with mechanical systems allowed them to adjust their maintenance routines to maximize equipment lifespan (Dennis, 2001: 10, 11]

Repair requirements were identified by a continuously ongoing facility assessment. In addition to repairs identified by employees or through normal facility maintenance activities, each member of the maintenance team would spend time each morning inspecting a portion of the campus. Over the course of a week, each maintenance team member had canvassed the entire property (Dennis, 2001: 10-14).

Dana proactively sought out potential problems by using a method they referred to as "predictive maintenance". Predictive maintenance involved monitoring their equipment for signs that problems may have been developing, in particular, bearing temperatures for all of their large motors. Increased bearing temperature indicated that the bearing may be failing or other problems (Dennis, 2001: 12-13).

M&R activities were fully documented in Dana's database. The database was extensive and supplied both the work schedule and a history of the work performed. An example of this was the extensive grounds maintenance records that tracked the various trees on the campus, their condition, annual growth, any fungal or viral problems, fertilization schedules, and so forth. Similar records were maintained for all of the systems that made up the facility such as chillers, boilers, air handlers, etc. (Dennis, 2001: 1, 14).

M&R Fund Allocation

Dana Corporation's corporate office used a combination of the LCC and CAT methods for M&R funds allocation. Estimated maintenance costs were prepared six quarters (18 months) in advance and based on the historical cost of providing facility maintenance to those facilities coupled with corporate predictions of the economy, fuel prices, etc. Repair requirements were typically identified well in advance of total failure and were therefore inserted into the six-quarter financial plan for execution at an appropriate time. Facility M&R requirements were viewed as part of the cost of doing business. (Dennis, 2001: 15).

Requirements/Allocation Integration

Facility M&R requirements were very closely connected to funds allocated to address those needs. Normal operating maintenance requirements were identified from the beginning, the cost to meet those needs were included in the budget six quarters in advance, and adjusted monthly to ensure accuracy. Repair requirements were typically identified through the preventive maintenance program or daily facility inspections and inserted into the schedule with adequate funding placed in the six-quarter financial plan (Dennis, 2001: 14-16).

An exception to this methodology only occurred during times of economic decline, such as that experienced during the fourth-quarter of 2000 and the first-quarter of 2001. During this time period, the automotive industry experienced lower demand for new vehicles. Additionally, the automobile manufacturers exerted pressure on their suppliers to reduce costs. In order to meet those realities, Dana was forced to reduce its workforce and mandated the implementation of cost savings at all levels. Facilities maintenance was

included in those measures, primarily as a signal that everyone with in the corporation, from the chairman of the board to the front line worker, was sacrificing to meet the economic needs of the company (Dennis, 2001: 5-7).

It should be noted, however, that this decision was not made without due reflection. Prior to implementing the reduction in facility maintenance allocation, the total impact was presented to the deciding officials. This presentation included both the short-term effects such as an increase in noticeable defects, as well as the long-term effects such as decreased equipment life expectancy, increased overall life-cycle costs, and increased risk of unscheduled repair requirements. Ultimately, the corporate board decided that sending the message that everyone within the corporation must reduce immediate costs outweighed the predicted increase in facility life-cycle costs (Dennis, 2001: 5-7).

Capitalization

Dana Corporation was pre-disposed to construct new assembly plants when and where needed. Their finished product was typically a large mechanical component such as truck frame rails, completed chassis, transmission assemblies, and axles. These assemblies are bulky, may require extra care in handling, and were usually expensive to ship great distances to customers. Locating near the customer lowered the overall cost of supplying the part and created a competitive advantage (Dennis, 2001: 3, 27).

An example of this was the recent announcement to construct a new plant in Longview, Texas. This plant was to support a General Motors assembly operation in Shreveport, Louisiana, less than 100 miles away. When bidding for the contract, the cost of the capital investment necessary to construct the assembly plant was included in the contractual bid (Dennis, 2001: 28).

Prior to making the decision to invest in facilities, a significant amount of documentation of the need and economic justification was required. First, the business group requiring the capital investment would quantify the actual need. This included the projected customers estimated quantity requirement, an in-house estimate of the same, and an economic analysis. A business case was then built which outlined these findings, payback periods, etc., after which the business group determined whether they truly need the capital investment in order to maintain or increase their profitability. If the decision was to proceed, a package was then prepared and presented to board members as a complete effort that described the need and justification of the requirement. At that point, the corporate board of directors functioned much like a bank. Once convinced of a requirement and shown a return on the investment, the funds would be allocated (Dennis, 2001: 28-30).

Table 5 presents the methods used by Dana Corporation to identify facility requirements and allocate funds for construction, maintenance, and repair activities. The facility managers identified construction requirements by specific need for new construction and condition assessment for existing facilities. Maintenance requirements were identified by a LCC methodology, where an initial maintenance program was developed at the beginning of a facility's or equipment items service life and was then followed throughout its life span. Repair requirements were identified by an assessment of the facilities condition. For each of the three activities, funds were allocated based on the identified requirement.

Table 5. Requirements vs Allocation for Dana Corporation

	Requirement Identification	Funds Allocation
Construction	Need/LCC	RI
Maintenance	LCC	RI
Repair	CAT	RI

Facility Maintenance Program Overall Impression

Dana Corporation's M&R program as implemented at their headquarters campus met all five of the criteria established for classification as an exceptional facility maintenance program.

Determine a desired level of facility quality.

Dana Corporation had explicitly defined their desired level of facility quality to ensure that the desired image is projected.

Adopted a method to determine the facility M&R requirements.

Dana Corporation's facility maintenance personnel went to great lengths to establish maintenance requirements for their facilities, installed equipment, and grounds. Maintenance requirements are based on manufacturer's recommendations, industry best practices, and in-house expertise. A continuous facility inspection process identified repair requirements.

Developed a method to allocate funds to meet those identified requirements.

Facility M&R requirements were funded using a six-quarter system that was updated monthly. Repairs and preventive maintenance activities were scheduled in advance to minimize if not eliminate the impact of that work on company productivity. Deferral of maintenance was avoided to the greatest extent possible and only permitted after significant review and full knowledge of the expected impact.

Take into account the eventual need for capitalization in the facility life cycle.

Capitalization requirements were addressed from a business decision point of view. A business case was built by the responsible business division that specified the investment requirement and included an estimated return on investment and pay back period. In the event of construction to support the needs of a new client contract, the investment costs were included in the contract.

Maintain facilities in excellent condition for type of work performed.

The facilities maintained by Dana Corporation's facility maintenance professionals were excellent for the work performed by the employees. Administrative offices provide an atmosphere that was conducive to the work performed, allowing employees to work comfortably.

General Motors Moraine Assembly Plant

Background

William Crapo Durant, a wealthy entrepreneur and salesman, is considered to be the father of the General Motors Corporation. Durant, who acquired his wealth through the Michigan horse-drawn carriage business, became the director of the Buick Motor Company in 1904. By 1908, he had built it into one of the largest automobile producer in the United States. In September of that year, Durant incorporated General Motors Company and quickly acquired Buick, Oldsmobile, Cadillac, and Oakland (which later became Pontiac). Durant even considered purchasing the Ford Motor Company, but decided that the $8-million price was too high (Keller, 1989: 39-40).

Over the next two years, Durant continued to expand GM, acquiring automakers in the US, Canada, and England. However, poor financial controls coupled with a mild

economic recession brought him to the brink of bankruptcy. Catastrophe was avoided when John H. McClement, a GM stockholder, stepped in with a consortium of bankers. This consortium provided $15-million in capital, but demoted Durant to a vice president with no real power (Keller, 1989: 40).

Over the next four years, Durant founded five motorcar companies apart from GM, including the Chevrolet Motor Company. Durant used the profits from these companies to purchase GM stock. By 1915, Durant held controlling interest in GM and once again was in control of the corporation. He again began acquiring companies such as Chevrolet and the Fisher Body Company. He also established the General Motors Acceptance Corporation (GMAC), the first company in the automotive industry that provided loans for car buyers, dealers, and potential dealership owners (Keller, 1989: 41-42).

A faltering economy again struck GM in 1920, leaving GM with no cash reserve, closed factories, and an inventory of unsold cars. Durant had also incurred a personal debt of about $38-million in purchasing shares of GM. Once again facing bankruptcy, a banking consortium lead by J.P. Morgan bailed Durant out, who then resigned from GM. He went on to found the Durant Motor Company which failed during the depression (Keller, 1989: 43-44).

After taking control of GM, J.P. Morgan implemented a reorganization plan drafted by Alfred P. Sloan. Sloan's plan was a corporate constitution with the goal of making GM manageable and profitable regardless of the state of the economy. To do this, he centralized control of the corporation while the control of engineering, manufacturing, and selling of cars was retained by experts within each division. The strategy worked and

GM prospered for decades, never suffering the financial crises that both Ford and Chrysler endured (Keller, 1989: 45-47).

A major shake-up occurred within the corporation with the Arab oil embargo of the early 1970s. The embargo led to an energy crisis, which caused the demand for large, inefficient cars to decrease significantly. GM was not structured to effectively design and produce small, fuel-efficient cars and compete with the imports from Japan and Europe. Throughout the 1980s, GM reorganized its corporate structure, improved relationships with unionized labor, acquired companies such as Hughes Aircraft Company and Electronic Data Systems (EDS) that added to their corporate strengths, and eliminated inefficiencies in the construction of automobiles. More importantly, GM remolded its corporate culture from the top down, embracing much of the continuous quality improvement philosophy. These changes made GM more competitive as it moved into the 21st century (Keller, 1989: 54-261).

At the time of this research effort, General Motors was the world's largest automotive corporation. General Motors employed more than 388,000 people and partnered with over 30,000 supplier companies worldwide with a global presence in more than 200 countries and manufacturing operations in 50 countries. Along with designing, manufacturing, and marketing of vehicles, General Motors had substantial interests in digital communications, financial and insurance services, locomotives, and heavy-duty automatic transmissions. GM had more than 260 major subsidiaries, joint ventures, and affiliates around the world (General Motors Corporation History, 2001: n.pag.).

GM's worldwide automotive operations were been combined into a single global unit. Known as GM Automotive Operations, it is composed of four regions: North

America; Europe; Asia Pacific; and Latin America, Africa and Mid-East. Original equipment and aftermarket automobile parts were distributed through a separate division, the Service Parts Operation (General Motors Corporation History, 2001: n.pag.).

In addition to automobiles and automotive parts, General Motors produced commercial-duty automatic transmissions and hybrid powertrains through their Allison Transmission operation. Likewise, rail locomotives and military vehicles were produced by GM Locomotive. Hughes Electronics provided satellite entertainment and communications (General Motors Corporation History, 2001: n.pag.).

Research of GM facility maintenance program was performed at the Moraine Assembly Plant (MAP), located in Moraine, Ohio. MAP was originally constructed in the 1950s as a manufacturing plant for Fridgidair® household appliances, a division of GM at the time. It was converted to manufacture small trucks and sport utility vehicles (SUV) in the early 1980s. Recently the facility was enlarged to provide additional floor space for the assembly of a new small truck/SUV introduced in 1999 (Dorsten, 2001: 9-10). Overall, the MAP appeared to be in above average condition for a facility of this age.

Descriptive Case Results

During a study performed during 2000-2001, General Motors corporate leadership determined that facility M&R investments were not being utilized as well as they could be. In particular, their study found that facility maintenance was being ignored until repairs were needed, which, in turn, increased the total cost of vehicle production. In response, GM established a central team called the World Wide Facilities Group (WWFG) to survey all of their manufacturing plants, suggest improvements, and establish facility M&R programs that would improve the quality of the facilities while reducing facility

related operating costs. The WWFG had arrived at the MAP about eight months prior to this research effort, MAP maintenance professionals were in the process of installing a commercially available maintenance software package and they had one person dedicated to inputting all of the equipment and facility data into the database (Dorsten, 2001: 1-3).

M&R Requirements Identification

At the time of this research effort, the maintenance work force at MAP used maintenance identification techniques common to the maintenance industry and may be classified as CAT. Maintenance requirements were established by equipment manufacturers recommendations and in-house experience. Those requirements were then placed in a computer database from which a daily maintenance work schedule was generated and specific tasks were assigned to each facility maintenance worker (Dorsten, 2001: 5]

The maintenance work force at MAP was increasing the use of proactive maintenance techniques. In particular, they were beginning to use thermography to check electrical panels and welding robots, vibration analysis for large fan and pump motors, and ultrasound to locate short circuits and air leaks. (Dorsten, 2001: 7).

At the time of this research effort, the maintenance work force at MAP had no repair requirement identification process in place. Rather, facility maintenance personnel depended on the tradesmen and repair technicians to identify repair requirements during the course of their daily routines. Once identified, a work-order for the repair was placed in the computerized system and scheduled for execution. The work was then performed as time permited and based on the urgency. Cost was also a factor, used to decide between repair and replacement (Dorsten, 2001: 5).

M&R Fund Allocation

Maintenance and repair allocation techniques may be classified as CAT. Maintenance cost-estimates were based on historical costs. Previous years maintenance requirements were inflated to cover the expected cost of the upcoming year and included in the annual budget. Funds for small repairs were also extrapolated from previous years expenses and provided for in the annual budget. Urgent repair requirements were addressed outside of the annual budgeting process. Once identified and documented, the requirements would be forwarded to the corporate headquarters for review. Funds would then be acquired by shifting them from another plant with less urgent requirements, reprogramming funds previously allocated to that plant by deferring other planned repairs, or by allocating additional funds (Dorsten, 2001: 10-12).

Requirements/Allocation Integration

The method of funding maintenance and repair requirements at MAP were not linked to the facility requirements in any structured way. Although historical costs were used, they might not have captured deferred or unobserved M&R requirements. With the exception of urgent repairs, funds were allocated based on macro historical costs and the expected increase due to inflation as opposed to a sum of the individual requirement cost estimates. These shortcomings in data collection prevented meaningful analysis of the underlying cost drivers related to facility M&R. This shortcoming should be overcome when their database becomes fully operational. As of the time of this research, no significant improvements had been realized by the facilities maintenance workforce at MAP (Dorsten, 2001: 10-12]

Capitalization

Capitalization decisions were based on the economics of building a particular product, i.e. a business case. GM's central office determined if a new product line was necessary. After reviewing the existing factories and future production plans, a location for the work would then be selected. At that point, any capital investment requirements would be calculated and evaluated in light of the expected profit. All of the capital investment decisions were made at the corporate level based on corporate identified requirements. The local plant facility manager had little or no input (Dorsten, 2001: 12,13).

Table 6 presents the methods used by General Motors Corporation to identify facility requirements and allocate funds for construction, maintenance, and repair activities. The facility managers identified construction requirements by specific need for new construction and condition assessment for existing facilities. Maintenance requirements were identified by a combination of LCC and CAT methodologies. LCC was used to prepare an initial maintenance regimen and the condition of the equipment or facility was taken into consideration as it aged. Repair requirements were identified by an assessment of the facilities condition. For each of the three activities, funds were allocated based on the identified requirement.

Table 6. Requirements vs Allocation for General Motors Corporation

	Requirement Identification	Funds Allocation
Construction	Need/CAT	RI
Maintenance	LCC/CAT	RI
Repair	CAT	RI

Facility Maintenance Program Overall Impression

As presented earlier, the facility maintenance program at GM's MAP was in a transitional phase during this research effort due to their recent review by the GM WWFG. The program being implemented appeared to be one that closely monitored the condition of facilities and would allow managers to make timely decisions that would meet their facility needs while minimizing their long-term facility costs. However, the program was not yet fully established and no current data was available.

GM's M&R program as implemented at the MAP met all five of the criteria established for classification as an exceptional facility maintenance program.

Determine a desired level of facility quality.

Prior to implementation of the WWFG, GM allowed each plant manager to determine his or her own level of facility condition. This decentralized method resulted in a large variance in facility condition between plants and no oversight of the facility investment being made on a corporate level. GM corporate management realized this disparity and established the WWFG to ensure that facility investments were made at the locations that provided the greatest financial benefit. GM determined the desired level of facility quality based on production goals such as minimizing the costs due to labor, down time, product fit and finish, etc. Through increased condition assessment and proactive facility maintenance activities, facility costs were minimized while ensuring the facilities met the requirements for vehicle production.

Adopted a method to determine the facility M&R requirements.

GM had adopted a method to determine the facility M&R requirements. They relied on the day-to-day maintainers to identify facility problems as well as an annual facility condition assessment. In order to manage these requirements, the managers at MAP had implemented a computer based database system. At the time of this research effort, the program was still being implemented.

Developed a method to allocate funds to meet those identified requirements.

The allocation method in place at GM MAP for maintenance and minor repair requirements was predominantly based on historical costs adjusted for inflation. Major repair requirements were documented and sent to GM corporate offices for funding.

MAP facility managers expect this process to change with the completion of Maximus implementation. Maintenance related costs will be accurately estimated and used for allocation. Additionally, repair requirements will become more visible, allowing better decisions between repair and replacement to be made.

Take into account the eventual need for capitalization in the facility life cycle.

Capitalization requirements within GM were determined at the corporate level based on the existing facility condition and expected future utilization requirements. The maintenance professionals at MAP relied on the division manager to determine and defend capitalization requirements. Facility capitalization decisions were economic based business decisions.

Maintain facilities in excellent condition for type of work performed.

Although showing the effects of past maintenance practices, the MAP appeared to be in adequate condition for the production of automobiles. GMs implementation of a

new division, whose sole focus was on facilities related requirements, indicated an increased emphasis on quality facility maintenance. At the time of this research, the program was a new work-in-progress and no results, either positive or negative, were yet available.

Mead Corporation

Background

Ellis, Chaflin & Co., the first direct forerunner of The Mead Corporation, was formed in 1846 in Dayton, Ohio for the manufacture of paper and wood pulp products. Colonel Daniel E. Mead participated as one of the partners. In 1881, Daniel E. Mead became sole owner of the mill and adopted the name The Mead Paper Company. The first issue of Mead stock was issued in 1906 and Mead then began to grow through the acquisition of mills, container manufacturing plants and paper related companies. Mead also pioneered coated paper technology through research efforts that resulted in the development of new products such as carbonless coatings and special coatings for color copiers and printers (Mead Corporation, 2001: n.pag.).

At the time of this research effort, the Mead Corporation produced pulp and paper, packaging and paperboard products, and was a leading maker of school and office supplies. Other Mead products included coated and uncoated paper, cotton-content paper, and specialty paper for printers and paper merchants. Mead had more than 15,100 employees with offices and operations in 32 countries. Mead was also a global manufacturing company with plants in Canada, France, Germany, Italy, Japan, Mexico, the Netherlands, Spain, and the UK (Mead Corporation, 2001: n.pag.).

Mead Corporation was headquartered in a 26-floor office tower located in Dayton, Ohio. This facility was constructed in 1976, had approximately 250,000 square feet of floor space, and occupied approximately half of the facility with the remainder leased to tenants. Occupancy rarely dropped below 100% (Mead Corporation, 2001: n.pag.).

Facility maintenance was performed by contract with the firm Jones, Lang & LaSalle (JLL), who had a one-year cost-plus-award-fee contract with option years. The contract was managed by a Mead Corporation vice president who relied on 1) inspection by facility maintenance experts visiting from other Mead Corp. plants and facilities, 2) complaints from employees and tenants within the facility, and 3) personal observation. JLL had a total of seven employees on site consisting of a supervisor/head engineer, a foreman, and five maintenance technicians (Hatton and Francis, 2001: 6-7).

Research of Mead Corporation's facility maintenance program was performed at the Mead Corporate Headquarters, located in Dayton, Ohio. This facility was purpose built in 1974 as the world headquarters for the Mead Corporation and has been purposefully well maintained and appeared to be in superb condition.

Descriptive Case Results

M&R Requirements Identification

Mead Corporation used industry standards, which may be classified as LCC methods, for facility M&R requirements identification. Facility maintenance requirements were developed from the initial occupancy of the facility using the equipment manufacturer's recommendations and the experience of the maintenance workers. Additionally, large system repairs, such as replacement of the facilities chillers and boilers, would be identified, it's cost estimated, and the work scheduled for

implementation at an appropriate time. Maintenance was not deferred as Mead is contractually obligated to maintain the facility at a certain level by contract with the tenants who make up fully one-half of the facilities occupants (Hatton and Francis, 2001: 2, 5).

There were three primary sources for facility repair requirements. The first and primary source was an annual audit. The audit consisted of a facility inspection performed by a corporate auditor familiar with facility requirements. In addition to a visual inspection of the facility, equipment maintenance logs were reviewed to ensure periodic maintenance was being performed and that repairs were discovered and made in a timely manner. During the audit, any facility requirements discovered by the auditor were noted and placed in the work schedule for execution at an appropriate time (Hatton and Francis, 2001: 2).

The second source for identifying repair requirements was through direct requests from the facility's owners. Mead Corporation leaders occasionally requests specific facility repairs such as upgrading the buildings lobby or washing and sealing the exterior of the facility. Estimates for these repairs were made by the facility maintenance foreman and financed by corporate leaders as funds became available (Hatton and Francis, 2001: 5).

The third source for identifying repair requirements was through customer notification. Tenants notified the facility maintenance staff of their needs through informal methods such as e-mail or chance meetings in the hallways. The staff would then log the requirement and perform the work at the earliest appropriate opportunity.

Relatively small requirements such as the replacement of ceiling lamps or repairing a broken doorknob would be quickly performed (Hatton and Francis, 2001: 5-6, 13).

M&R Fund Allocation

M&R requirements were funded through an annual budget, which was prepared in September of each year. The facility budget estimate was prepared by the JLL contract Facility Engineer and included the costs associated with the planned facility and equipment maintenance, typical small facility repairs, and any planned projects. Scheduled maintenance and typical small facility repairs were not deferred. However, planned projects that did not negatively impact the facility condition or violate contractual obligations were sometimes deferred. An example of a planned project that met these requirements was a lobby renovation (Hatton and Francis, 2001: 3, 6-7]

Requirements/Allocation Integration

The allocation of funds at Mead for facility maintenance requirements was strongly related to the identified requirements. Although economics dictated the total funds available, facility M&R requirements were not deferred. There were two reasons for this approach.

The first reason for not deferring facility M&R was that Mead desired to project a good image of the company within the industry. The particular facility studied during this research effort was the corporate headquarters for a global business and was often visited by executives from both Mead Corporation and their customers. As such, a comfortable, well-maintained facility was thought to add prestige to Mead Corporation's image (Hatton and Francis, 2001: 11-12).

The second reason for not deferring facility M&R was that over fifty percent of the facility was leased to tenants. One of Mead's goals was to keep the facility's occupancy level as high as possible. Mead's leadership believed that the prestige of their facility coupled with excellently maintained office space could be attributed to their success in keeping all of the offices excess to their own needs leased (Hatton and Francis, 2001: 11-12).

Capitalization

Mead Corporation considers capitalization as a business decision, based on the economics surrounding the particular requirement being addressed. The headquarters facility had not required any capital expenses since initial construction. Other locations require building a business case where the cost of the investment could be compared to the benefits derived from that investment (Hatton and Francis, 2001: 14).

Table 7 presents the methods used by Mead Corporation to identify facility requirements and allocate funds for construction, maintenance, and repair activities. The facility managers identify construction requirements by specific need for new construction and condition assessment for existing facilities. Maintenance requirements were identified by a LCC methodology. Repair requirements were identified by an assessment of the facilities condition. For each of the three activities, funds were allocated based on the identified requirement.

Table 7. Requirements vs Allocation for Mead Corporation

	Requirement Identification	Funds Allocation
Construction	Need/LCC	RI
Maintenance	LCC	RI
Repair	CAT	RI

Facility Maintenance Program Overall Impression

The facility maintenance program at Mead Corporation's headquarters facility was long established and fully operational. The facility was well maintained and suited for use as a world headquarters facility. In addition to well-maintained and appointed administrative suites, the mechanical systems were up to date and reliable. The result was a facility that was prestigious in appearance and in high demand.

Mead Corporation's M&R program as implemented at their headquarters facility met all five of the criteria established for classification as an exceptional facility maintenance program.

Determine a desired level of facility quality.

Mead Corporation determined that the level of facility quality should be reflective of their status as a global corporation. Their facilities M&R program ensured that the facility projected that image to clients and the community while assuring the underlying infrastructure was always operational.

Adopted a method to determine the facility M&R requirements.

Mead Corporation's contractor was responsible for identifying facility M&R requirements. Those requirements were gathered from equipment manufacturers recommendations, annual inspections, and tenant requests, all of which were generally accepted industry standards.

Developed a method to allocate funds to meet those identified requirements.

Mead Corporation allocated funds to meet annual facility maintenance requirements based primarily on historical maintenance costs and included these costs in the annual budget. Likewise, minor repairs were estimated and provided for in the annual budget. Major repairs were provided for through special funding from Mead Corporation's corporate headquarters. No thought had been given to developing a computer based system to accurately predict facility M&R costs; however, the single-purpose nature of the facility – a high-rise office tower – minimized the number of facility maintenance variables, allowing the simple historical based estimates to predict future facility related expenses to an acceptable level of accuracy.

Take into account the eventual need for capitalization in the facility life cycle.

Capitalization requirements were addressed from a business decision point of view.

Maintain facilities in excellent condition for type of work performed.

The facilities maintained by the Mead Corporation provide a superior office environment for businesses requiring outstanding administrative surroundings.

NCR Corporation

Background

John H. Patterson originally founded the present day NCR Corporation in 1884 as the National Cash Register Company. NCR's product at that time was mechanical and later, electric motor powered cash registers. NCR began to branch out of this market in 1953 with the acquisition of Computer Research Corporation (CRC) of Hawthorne, California, which produced a line of digital computers with applications in aviation. NCR

continued to develop electronic applications for business machines through the 1960s and 1970s (NCR Corporation , 2001: n.pag.).

In 1982, NCR introduced a supermicrocomputer system, which established NCR as a pioneer in bringing industry standards and open systems architecture to the computer market. In turn, NCR purchased Teradata Corporation, where it acquired its commercial parallel processing technology in 1991 and continued its shift towards becoming a complete computer solutions provider by acquiring several specialized software companies. In 1998, NCR finalized the transfer and sale of their computer hardware manufacturing business allowing them to focus the software and services. Today, NCR is a leading e-businesses software solutions provider to companies such as Travelocity.com, E*Trade and Microstrategy (NCR Corporation , 2001: n.pag.).

The Dayton NCR operation employed 21,000 workers and maintained 33 facilities at its peak. With the shift in focus from the manufacture of electromechanical and computing devices to development and distribution of computer software solutions, the workforce at the Dayton campus has declined to about 3,500 workers in 12 facilities. The disposal of two additional factory-type facilities acquired in the 1950s is scheduled for the summer of 2001. At that point, NCR will maintain approximately 1.5 million square feet of predominantly administrative space (Freeman and others, 2001: 1-3).

Research of NCRs facility maintenance program was performed at the NCR World Headquarters campus, located in Dayton, Ohio. The remaining facilities were a combination of dedicated administrative office space, dedicated software development facilities, and older factory-type facilities that had been converted to administrative space. Overall, these facilities appeared to be of average condition for their age.

Descriptive Case Results

As NCR transitioned from an electro-mechanical manufacturer to a computer solutions provider, they were left with facilities that no longer met their needs. The headquarters building was constructed in the 1970s; however, the bulk of the rest of the campus facilities were factory buildings constructed in the 1940s and 1950s. Although some of these facilities were converted to administrative office space, most were razed when they were no longer needed (Freeman and others, 2001: 3).

NCR executives view this strategy as providing two distinct benefits. First, it removed the burden of maintaining old facilities. These old facilities were designed for manufacturing production, so were not well suited for use as office space. The second benefit was the projection of a positive image. Most of NCR's competitors were relatively new companies operating from modern office buildings. Old factory buildings converted to administrative space did not project the image of NCR as a firm that was as competitive and agile as their rivals (Freeman and others, 2001: 3-4).

Although not a primary concern, NCR executives and facility managers took the condition of the facilities into consideration as part of their human resources effort. Older, poorly maintained facilities did not appeal to the types of employees that NCR needed in order to be competitive. To attract and retain the skilled employees NCR required to be competitive, they were determined to maintain their facilities at a quality level consistent with the levels provided by their competition. (Freeman and others, 2001: 11]

NCR had also gone through a significant change in managing their facilities over the past two decades. Prior to 1980, facilities were viewed as part of the assets for the business unit. In order to maximize their units' profit, effective facility maintenance

programs were often neglected and repairs were regularly made only after a failure had occurred (Freeman and others, 2001: 11-12).

During the 1980s, NCR shifted to a centralized campus facilities maintenance group. The centralized campus facilities maintenance group was responsible for all facility related requirements on the Dayton NCR campus, allowing for increased effectiveness and decreased costs for the management of their property. With a professional facilities maintenance team, facilities decisions could be made to most benefit the company while lowering the overall facility maintenance costs (Freeman and others, 2001: 12).

Beginning in 1995, NCR again transitioned to a new facility management program. In order to focus on their core business, they shed non-core business activities. The company outsourced business services to Xerox Business Services, food service and vending to Sodexho Marriot Services, and facilities maintenance to Jones Lang LaSalle (JLL). This allowed NCR to utilize the economies and expertise of specialists while reducing their own workforce and freeing up capital for their own core business. Where previously NCR had 350 facility maintenance personnel, only five were needed to oversee the facilities maintenance contract after outsourcing (Freeman and others, 2001: 1-3, 12).

The combination of these efforts allowed NCR to transition into facilities that best met their needs. An additional technique used was to reduce the amount of space allocated to employees, in effect, squeezing them into smaller offices and cubicles. A second method was the use of “alternative officing”, which was their term for setting up the necessary equipment and connectivity for an employee to telecommute from home. Through the use of these methods, NCR was able to eliminate the requirement for two

factory buildings that had been converted to office use. At the time of this research effort, these two facilities were scheduled for demolition in June 2001.

M&R Requirements Identification

NCR used a CAT method for facility M&R requirements identification. During the transition from the centrally managed facility maintenance organization to an outsourced contract for facility services, a condition assessment of the facilities was included in the contract. Facility maintenance requirements were developed from manufacturer's recommendations for the existing installed equipment, the experience of the maintenance workers, and industry best practices. These requirements were defined in the contract as the scope of work (Freeman and others, 2001: 7-9, 12-13).

Although significant improvements had been made, NCR still had a considerable backlog of maintenance and repair requirements at the time of this research effort. The backlog was attributed to the poor past practices coupled with the age of the facilities. The current maintenance team viewed themselves as being more reactive than proactive with approximately 30% of requirements classified as maintenance and 70% as repair. NCR's goal was to improve that to 60% maintenance and 40% repair. In order to meet that goal, JLL was tracking all of the requirements and were compiling a trend history. Once they have documentation that describes precisely what systems or equipment items are driving the repair costs, projects will be programmed and planned to correct the problems, leading to a reduction in annual overall all M&R costs (Freeman and others, 2001: 13-14).

M&R Fund Allocation

NCR funded their facility M&R requirements using a CAT methodology. Maintenance requirements were estimated from historical costs, where as, repairs were funded through a pliant capital budget. In both cases, JLL's on-site supervisor were required to prepare the annual budget requirement and work with an NCR accountant to defend it to NCR's corporate executives. Next, the NCRs Director of Property Services reviewed the requirements and imposed any monetary reductions that were necessary due to budget constraints. Finally, the requirements were rank ordered and an assessment of risk was made. These ranked requirements were then sent up to the corporate level where funds were allocated based on the requirements and economic constraints. In the event that the corporate office provided inadequate funds to cover all of the requirements with unacceptable risk assessments, funds allocated to other sites such as Atlanta or San Diego would have been redirected to the Dayton campus (Freeman and others, 2001: 8, 15-18).

Requirements/Allocation Integration

Fund allocation for facility maintenance requirements was based on the identified facility requirements; however, corporate economics dictate final total amount that was available. The Director of Property Services performed a continuous balancing act between facility requirements and limited funds (Freeman and others, 2001: 4, 9, 10, 16).

NCR corporate leaders had mandated that facility M&R costs decrease each year. Much of the cost savings realized in the past were due to the economies of first centralizing facility maintenance for the entire campus, followed by outsourcing the facility maintenance activities to a facility maintenance specialty firm, namely, JLL. JLL has been able to continue the annual cost savings by ensuring that all replacement

equipment was energy efficient and incorporated advanced technological processes. (Freeman and others, 2001: 4, 9, 10, 16).

NCR and JLL had a goal of allocating 60% of their M&R budget to maintenance and 40% to repair. The allocation constraint of reducing facilities M&R costs each year prevented them from restoring the facilities to a condition where only sustainment costs were the major requirement. NCR was using their plans for demolition and future capitalization to eventually overcome this deficiency (Freeman and others, 2001: 13-14]

Capitalization

Due to their fundamental shift from producing electro-mechanical equipment to providing software solutions, NCR had an excess of facility space and therefore had no pressing requirements for new facilities. However, all major facility renovations in the past were capitalized and future requirements were expected to be capitalized or re-capitalized as the case may be. The first step was to build a business case, which defined the need, described the scope of the project, and presented the expected results of not doing the project. Age and future use of the facility were considered and an economic analysis including an estimate of the return on investment was also provided. Once approved, a capital appropriation request would be made and the funds allocated upon approval(Freeman and others, 2001: 18-19).

Table 8 presents the methods used by NCR Corporation to identify facility requirements and allocate funds for construction, maintenance, and repair activities. The facility managers identified construction requirements by specific need for new construction and condition assessment for existing facilities. Maintenance requirements were identified by a combination of LCC and CAT methodologies. LCC was used to

prepare an initial maintenance program for large investment items such as chillers and the condition of the equipment or facility was taken into consideration as it aged. Repair requirements were identified by an assessment of the facilities condition. For each of the three activities, funds were allocated based on the identified requirement.

Table 8. Requirements vs Allocation for NCR

	Requirement Identification	Funds Allocation
Construction	Need/CAT	RI
Maintenance	LCC/CAT	RI
Repair	CAT	RI *

* Subject to Availability of Funds

Facility Maintenance Program Overall Impression

Over the course of two decades, NCR implemented two major transitions to their facilities M&R program. Before 1980, NCR's corporate leadership allocated facilities to the various divisions, each of which performed their own facility M&R. NCR's corporate leadership determined that this method had a severe drawback in that there was no incentive to maintain the facilities and some division leaders would defer maintenance to boost their short-term profits without regard to the long-term impact to the condition of the facilities.

In 1980, NCR's corporate leadership implemented a centralized facility M&R division to address the facility needs of the Dayton campus. The division was responsible for analyzing the needs of all divisions located on the Dayton campus, prioritizing those needs, and advocating for funds to meet those that were considered to be critical. Some

cost savings were realized by eliminating the need for duplicate positions common to more than one division.

In 1990, NCR's corporate leadership transitioned to a contracted centralized facility M&R program and reduced their in-house facility M&R division from over 300 technical professionals and laborers to five people to provide oversight of the contract. This transition had several benefits. First, it allowed NCR's corporate leadership to focus on the business's core competencies with minimal impact from non-core efforts. Second, this transition resulted in reduced facility M&R cost for the same level of effort due to the contractor's ability to utilize economy of scale in the service provided.

NCR's M&R program as implemented at their Dayton campus met all five of the criteria established for classification as an exceptional facility maintenance program.

Determine a desired level of facility quality.

NCR's facility maintenance managers established a definitive level of facility quality based on the function served by that facility. However, the facility M&R manager constantly sought to balance the desires of the company leadership to provide exceptional facilities with the reality of a limited budget for facility M&R requirements.

Adopted a method to determine the facility M&R requirements.

Facility M&R requirements were defined in the contract they had with their outsourced facility maintenance contractor, JLL. Facility maintenance requirements were defined and followed the equipment manufacturers recommendations. Proactive maintenance practices were used to identify repair requirements as well as an annual facility inspection.

Developed a method to allocate funds to meet those identified requirements.

NCR's executives allocated funds to meet annual facility maintenance requirements based primarily on historical maintenance costs and included in the annual budget. Likewise, minor repairs were estimated and provided for in the annual budget. Major repairs were provided for through special funding from NCR's corporate headquarters.

Take into account the eventual need for re-capitalization in the facility life cycle.

Capitalization and re-capitalization requirements were addressed from a business decision point of view.

Maintain facilities in excellent condition for type of work performed.

NCR's facilities were, overall, in good condition considering the age of the structures and acceptable for administrative and software development work. However, the facility maintenance workforce spent a significantly greater amount of time maintaining the facilities than would have been the case had they been adequately maintained. NCR was making efforts to further consolidate their personnel from two older converted factories into dedicated office buildings, allowing them to demolish the factory buildings. This effort was expected to reduce their maintenance efforts by removing the two most maintenance intensive facilities from their inventory.

USAF

Descriptive Case Results

M&R Requirements Identification

The USAF had established a thorough program for the identification of facility and infrastructure M&R requirements. Each installation was responsible for performing a MAJCOM approved M&R program and all facility and infrastructure M&R requirements were documented at the installation level. The documentation included a record of the existing conditions, manufacturers recommendations, and written justification. When required, this data was shared with the installations MAJCOM and/or HQ USAF.

Preventive maintenance requirements were developed from manufacturers recommendations, industry best practices, and the experiences of the facility maintenance professionals at each individual installation. Most installations had implemented several proactive maintenance activities such as thermal scanning of electrical panels and overhead distribution systems.

Facility repair requirements were identified during annual facility inspections or reported by personnel working there. Minor repairs were worked into the schedule of the maintenance crew responsible for that facility. Major repairs were occasionally accomplished by this same crew, although most were carried out through contracted means. By contracting out large requirements, the in-house facilities maintenance teams could then focus on their primary responsibility, which was scheduled maintenance requirements.

Facility construction requirements were differentiated by those needed for new mission responsibilities and those supporting current missions. New mission requirements

were typically identified during the planning phase of a new mission beddown. Typically, a multi-discipline team composed of experts from both the MAJCOM and installation would meet to ensure that all of the beddown requirements were included in the plan. Requirements necessary to continue an assigned mission were planned and programmed by the local installation with MAJCOM oversight. In both cases, existing facilities were repaired to meet the missions requirements when economically feasible.

M&R Fund Allocation

Funds for facility related work were provided to the USAF through three specific congressional appropriations. These appropriations were:

- Department of Defense (DoD) Appropriation: Primary source of funds for minor construction projects (less than $500,000) and facility M&R requirements
- Military Construction (MILCON) Appropriation: This source provided funds for new construction in excess of $500,000 and large (typically in excess of $2,000,000) repair projects
- Department of Energy (DoE) Appropriation: Provided M&R and minor construction funds for DoE research facilities located on USAF installations

Each of these three avenues began with passage of the President's Budget and were based on the stated needs of the DoD or DoE with heavy emphasis placed on historical allocation rates. Maintenance requirements were estimated at 1.00% and repair requirements at 0.75% of the USAF plant value. The MILCON allocations consisted of specific line item lists of facility requirements and amount provided for each.

Once the Air Staff received the allocations, they disbursed the funds to the MAJCOMs based on PV. At the time of this research effort, the Air Staff was still redirecting 0.75% of the USAF plant value to force modernization.

The MAJCOM then disbursed the funds to the various installations, typically on a quarterly basis. Maintenance requirements were funded based on the installations PV. Repair requirements were funded in one of two ways at the discretion of the MAJCOM. Many MAJCOMS based their allocation of repair funds on the installations percentage of the MAJCOMs repair requirements as reported through the FIM; others still base repair allocation on the installations PV.

Requirements/Allocation Integration

Facility M&R allocation was poorly coupled to the identified facility M&R requirements. Funds from Congress to the Air Staff and from the Air Staff to the MAJCOMs were based on historical allocation rates and PV. In turn, MAJCOMs allocated funds to their installations in several methods. Funds for facility maintenance requirements were allocated based on an installations PV in comparison to the PV for the MAJCOM. Funds for facility repair were allocated in one of two ways: 1) based on an installations PV in comparison to the PV for the MAJCOM or 2) based on actual facility repair requirements. Allocation was further decoupled from the identified requirements by the intentional redirecting of funds from facility repair to force modernization requirements.

Capitalization

Facility capitalization was performed primarily through the MILCON program. New construction was avoided if existing facilities met the mission's requirements or may be economically repaired are available. In the event that the facility repair would exceed 70% of the construction cost for a new facility, a new facility was warranted.

Table 9 presents the methods used by the USAF to identify facility requirements and allocate funds for construction, maintenance, and repair activities. The facility managers identified construction requirements by specific need. For new USAF programs, such as bedding down a new type of aircraft, funds were allocated for construction based on the identified requirements. However, construction requirements for existing activities, such as adding a wing to an education center to accommodate increased usage, competed with other installation identified construction and repair requirements for the limited funds made available based on the installations PV. Maintenance requirements were identified by a combination of LCC and CAT methodologies. LCC was used to prepare an initial maintenance program and the condition of the equipment or facility was taken into consideration as it aged. Funds were allocated to maintenance requirements based on 1.00% of an installations PV. During the period of time that this research effort was taking place, facilities maintenance leaders within the HQ USAF were implementing the FSM and directing the MAJCOMs to begin allocating maintenance requirements based on its predictions. Finally, repair requirements were identified by an assessment of the facilities condition. Funds were then allocated based on facility condition (FIM rating) and the installations PV.

Table 9. Requirements vs Allocation for the USAF

	Requirement Identification	Funds Allocation
Construction	Need	RI/PV
Maintenance	LCC/CAT	PV
Repair	CAT	PV/CAT

Facility Maintenance Program Overall Impression

The facility maintenance program in use by the USAF has evolved over time. At the time of this research effort, the USAF used four well-defined programs to perform facility construction, maintenance, and repair. These programs described in detail in Chapter II, Section "USAF Methodologies. Although well developed, the M&R program as implemented by the USAF did not meet all five of the criteria established for classification as an exceptional facility maintenance program.

Determine a desired level of facility quality.

The USAF determined that the desired level of facility quality is achieved when a facility meets the mission requirements for which it is intended and requires no workarounds or repairs.

Adopted a method to determine the facility M&R requirements.

Facility maintenance requirements were developed from manufacturers recommendations and the experiences of the maintenance technicians.

Repair requirements were identified during annual facility inspections or as reported by personnel working in that facility. These facility and infrastructure requirements were then compared with the desired facility quality level through the use of the FIM where mission and condition were used rank order the requirements.

Developed a method to allocate funds to meet those identified requirements.

The USAF had developed methods of allocating funds to meet the identified requirements. Maintenance requirements were estimated through the FSM and MAJCOMS were directed by HQ USAF policy to allocate funds for maintenance requirements based on the FSM estimate. However, the funds allocated from HQ USAF

to the MAJCOMs for maintenance was still based on PV. Although the amount allocated closely approximated the requirement, the two were not connected other than through the 1.00% of PV rule of thumb for facility maintenance requirements.

The program for allocating funds for repair requirements was based on the installation and MAJCOM PV. However, the actual allocation of funds did not match the documented requirement. Project FIM ratings were used to insure that the limited funds that were available were used to fund requirements that had the greatest mission impact.

Take into account the eventual need for capitalization in the facility life cycle.

The USAF facility maintenance program was established to maximize the life expectancy of the facilities in the USAF inventory. Repairs were required to overcome damage due to storms, accidents, and the effects of differed maintenance. However, facility renewal either by replacement or extensive repair was not accounted for in the current facility maintenance program.

The USAF used a process similar to a commercial business case to evaluate the economics of facility investments. Programming documentation was prepared to justify project requirements and included an independent economic analysis to determine a probable period to recover the investment. This assessment was based on mission impact.

Maintain facilities that are in excellent condition for the type of work being performed.

Many of the facilities in use by the USAF fail to meet this requirement, requiring user support and work-arounds to ensure the primary mission is accomplished.

Cross Case Analysis

Each of the companies interviewed were top performers in their respective fields. At the point in time while this research effort took place, General Motors and Daimler-Chrysler were first and third respectively in the global automotive industry, Dana Corporation was the leading supplier of vehicle parts and assemblies to the automotive industry world-wide, Mead Corporation was the leading supplier of raw and finished paper products in North America, and NCR Corporation was the leader in computer systems solutions (Fortune, 2001;n.pag.).

Each of these companies used similar methods for facility maintenance requirement identification. Each relied on a combination of the manufacturers recommendations and their own in-house expertise to determine the requirements needed for the maintenance of their facility investment. To varying degrees, each also used one or more forms of preventive/proactive maintenance to detect impending failures and make repairs before a failure would impact their production. These proactive maintenance techniques included:

- Thermal imaging to detect electrical problems in panels, overhead wiring, and substations and robotic welding systems
- Bearing vibration and temperature analysis to detect approaching failure in large rotating assemblies such as chillers and fans
- Eddy current testing of chiller and/or boiler tubes
- Ultrasonic analysis to detect compressed air leaks and failing electronic components

Each of these companies used similar facility maintenance requirement allocation methods. A common thread through them all was the use of the actual facility maintenance requirements as the basis for allocating the facility maintenance effort. One company in particular, Dana Corporation, included the cost of facility maintenance in their business analysis prior to acquiring a facility and avoided deferring maintenance activities if at all possible. Although they had high maintenance activities and corresponding costs, they had virtually no repair requirements. Those few repairs needed were identified and planned well in advance to avoid impact to their business.

NCR also used the maintenance requirements to determine the allocation rate. However, they relied on historical costs for a baseline with an emphasis on continual improvement to drive down their maintenance costs.

In contrast, facility maintenance allocation at Daimler-Chrysler TNAP was directly related to the production of vehicles. Facility maintenance requirements that could be directly related to the quality of the vehicle, such as periodic replacement of filters in the paint booth, were included in the annual operating budget and were attributed to the production cost of each vehicle produced. Facility maintenance requirements that were not directly related, such as replacing a flickering fluorescent lamp in an administrative office, were routinely deferred until one of the maintenance workers could work it into his or her schedule.

In contrast to facility maintenance requirements identification, repair requirement identification ranged from an informal daily facility inspection to an attitude of making repairs after a failure if it impacted production or there was enough spare time in a maintenance workers schedule. The informal daily inspections at Dana ensured that each

of the facility maintenance workers observed a portion of the building everyday and covered the whole building in the course of each week.

Individual employees also brought repair requirements to the maintenance team's attention. Companies such as Mead Corporation relied on employees to identify problems and e-mail the requirement to the facility supervisor. Daimler-Chrysler's TNAP maintenance supervisor relied on employees in a similar fashion but also incorporated an inspection of the facility in a given area whenever equipment was being maintained or replaced.

Much like facility maintenance requirement allocation, facility repair requirement allocation was typically based on the identified requirement. Dana used the identified requirement to plan the actual repair up to 18 months in advance, allowing them to acquire all of the necessary parts and tools and schedule the repair to a time when it would least affect productivity.

NCR used a unique risk analysis technique that rank-ordered their repair requirements. NCRs corporate managers reviewed the requirements and allocated funds to meet the repair requirements by funding the repairs that posed the highest risk to corporate productivity first, followed by decreasingly risky requirements until the available funds were exhausted. If adequate funds to perform the projects with substantial risk were not available, methods of redirecting funds from other NCR campuses could be employed.

Daimler-Chrysler's TNAP, again, used the impact of the requirement on vehicle production as the measure to determine the merits for funding facility repairs. Facility requirements were typically deferred unless they directly impacted the production of

vehicles or were easily repairable by a maintenance technician with time in his or her schedule to do the work. TNAP's facility maintenance supervisor was aware that the long-term effect of deferred M&R would be a slow degradation of the facility. The Jefferson Street Assembly Plant (JSAP) was constructed about ten years prior to TNAP and documentation of JSAP operations indicated that the practice of deferred M&R lead to a backlog of M&R requirements that required several full-time employees. In spite of the data from JSAP, TNAP managers considered deferring the M&R requirements as a good business practice and accepted the future degraded facility condition and subsequent higher M&R costs in order to minimize their present overall costs.

Strong conclusions cannot be drawn on these five companies views of capitalization. The facility managers interviewed were not always involved in their respective company's capitalization program and, of the three that were involved, each indicated that the decision to invest in a facility was predominantly an economic decision driven by a detailed analysis of the problem being addressed, cost of alternatives, impact of the various alternatives to corporate profits, etc. The ultimate decision to finance a capital project rested with a headquarters board of directors.

Like the majority of the companies researched, the USAF had developed techniques to identify facility maintenance and repair requirements that were well thought out and capable. Maintenance requirements were developed from manufacturers recommendations and typical maintenance practices. Repair requirements were determined through condition assessment of facilities and infrastructure. The FIM program was used to rate facility repair projects based on the impact of the facility

condition on the activities housed in the structure and how that activity was associated with the mission of the installation.

However, funds allocation to meet the identified requirements was more closely tied to the requirement for the most of the corporations than for the USAF. Dana Corporation, in particular, allocated funds for maintenance and repair requirements based directly on the known and predicted costs. Daimler-Chrysler, General Motors, and Mead Corporation each allocated funds based on the requirements but placed limitations on funds based on historical needs. NCR corporation, like the USAF, used the known requirements as a method of distributing a predetermined amount of funds.

Table 10 is a compilation of the information presented in Table 4 through Table 9, and presents the methods used by each of the five companies researched and the USAF for identifying facility requirements and allocating funds for construction, maintenance, and repair activities.

Table 10. Requirements vs Allocation for Five Companies and the USAF

	Construction		Maintenance		Repair	
Company	Reqmnts	Alloc	Reqmnts	Alloc	Reqmnts	Alloc
Daimler-Chrysler	CAT	RI	CAT	RI	CAT	RI
Dana	LCC	RI	LCC	RI	CAT	RI
General Motors	CAT	RI	CAT	RI	CAT	RI
Mead	LCC	RI	LCC	RI	CAT	RI
NCR	CAT	RI	CAT	RI*	CAT	RI*
USAF	CAT	RI	CAT	PV	CAT	PV/CAT*

* Both NCR and USAF have methods identified for allocating funds for identified requirements; however, both have greater annual requirements than available funds. The result is that both develop lists of requirements prioritized in order of descending criticality and fund the most urgent requirements with the limited funds available.

Summary

This chapter presented the five case studies obtained during the course of this research effort. First, a review of the facility M&R programs was presented for each

company. This was followed by a cross case analysis, which compared and contrasted the programs of the five companies.

V. Conclusions and Recommendations

Chapter Overview

This chapter provides a review of the research questions and a short summary of the associated findings. Next, conclusions drawn from the research will be presented, accompanied by a presentation of the limitations of the research effort. Finally, recommendations for further research will be presented.

Findings

Dana Corporation set very high facility maintenance standards that were rigorously adhered to except during economic recession. Dana was a primary supplier of chassis components and systems to both General Motors and Daimler-Chrysler. Dana's use of excellent facilities maintenance practices was stated as being responsible for the high level of production obtained from Dana's employees, which offset the higher cost of maintenance. Despite the additional cost of their aggressive facility M&R program, Dana Corporation remained competitive within their industry, underbidding their competition for contracts with General Motors and Daimler-Chrysler. Arguably, Dana Corporation would not be able to maintain their facilities at such a high level of quality and still compete successfully with other automotive parts suppliers if their increased level of facility M&R expenses significantly detracted from the company's profitability. One would expect that if the practice of deferring M&R requirements gave a company a competitive edge, all companies in that industry would mirror each other in their M&R practices. Dana Corporation is an example of the opposite of that expectation. Despite a significantly higher than average emphasis on facility maintenance, they were the leaders

of their industry. Their facility M&R program and consequent condition of their facilities stood in stark contrast to two of the companies they supplied parts and equipment to.

General Motors MAP was a significantly older facility that outwardly appeared to be well maintained. Until recently, their view of facility maintenance was much like that at Daimler-Chrysler TNAP: repairs were made only when the lack of repair would adversely impacte vehicle production. Little long-term facility planning was performed. Recently, General Motors researched the cost attributed to facility maintenance and discovered they could not account for it accurately. They formed a group at the corporate headquarters level to address facilities issues across the entire corporation and set up a process where facility maintenance requirements could easily be tracked. Facility maintenance requirements now have the same visibility as vehicle production. Although improvements in facility condition and lowered costs are expected, the program was only recently implemented and no data was available to determine if it was producing the expected results.

Daimler-Chrysler's TNAP is a new factory using the latest in automation. Bringing TNAP on line was reported to be the best factory start-up in Daimler-Chrysler history. In order to reduce operating costs, all facility maintenance that did not directly impact the production of vehicles was deferred in spite of the fact that other assembly plants within the corporation indicated that a full time facility maintenance crew would be required within a few years to address a backlog of requirements that resulted from the deferral.

This analysis suggests that increased facility condition and maintenance allocation is not directly correlated to an increased overall cost of production. The companies with

the least proactive and least funded M&R programs (GM and D-C) both purchased many of their components from the company with the most proactive and well funded maintenance program (Dana Corporation). The condition of these companies' facilities had little to no impact on their ability to compete in the marketplace, if the M&R program were properly instituted and supported from the inception of the facility. High investment levels in maintenance activities appear to result in no difference in the companies' ability to compete within it's market segment nor to provide the same level of productivity while providing a substantially better quality of life for the employees in the form of a superior work environment.

A second observation is that a lack of commitment to facility maintenance may lead to future increased repair costs that may be insurmountable without a disproportionately high cost. Three of these companies stand out in this regard. Dana Corporation viewed the quality of their facilities as a key part of their mission and accepted the cost of high facility maintenance; a decision that resulted in a facility in constant use for over thirty years that was in like-new condition. Conversely, NCR and Daimler-Chrysler both have documented evidence that deferred maintenance lead to degraded facilities and increased costs. Once a backlog of maintenance and repair requirements was established, many corporate leaders found it difficult to justify the perceived high cost of restoration and instead opted to fix what they could for a price and live with what they determined they could not afford to fix.

A third observation is that facility managers who were forceful proponents of facility requirements seemed to have better results getting the funds needed to perform M&R activities. Facility maintenance must support the mission of the facility; however,

advocates for quality facilities got their message across better because they believed the need was valid for the long-term benefit of the company. Managers with short-term views tended to have poorer facilities.

A good example of this is a comparison of NCR Corporation and Dana Corporation. The past practice at NCR was to defer M&R until a repair was required. In the short term, this increased the profits of that division; however, in the long-term, the facilities deteriorated to the point where operational maintenance levels were intense and facility replacement was economically more feasible than restoring them to a useful condition.

In contrast, Dana Corporation had proactively maintained their facility from the first day of occupancy. Although over 30 years old, it looked and operated as if it the ribbon cutting ceremony were yesterday. Potential problems were identified early; plans for correcting these problems were made and acted upon before they could impact the companies operations. The benefit of this method was that Dana enjoyed zero downtime coupled with employee productivity, which was considered to be exceptional by Dana's executives.

Conclusions

Each of the companies included in this research effort allocated funds to meet facility M&R requirements based on those requirements with consideration in varying degrees to the impact on their corporate goals, impact on their employees, and the economic realities of the company. Corporate goals included production of goods or services, projection of a desired image, and shareholder profitability. These companies considered the impact of the facility's condition instrumental in attracting and retaining

the best employees in a competitive market place and increasing their employee's productivity while on the job. These differences imply several conclusions.

First, the relationship between Daimler-Chrysler Corporation, Dana Corporation, and General Motors suggests that a corporate commitment to providing quality facilities does not increase production costs or decreases profitability. In the competitive automotive industry, Dana Corporation was the most successful provider of quality automotive assemblies and their decision to defer facility maintenance was to demonstrate to their employees that they would all suffer together during economic downturns, despite their belief that their long-term best interest was to maintain facilities to an exceptional condition level.

There are several comparisons that can be drawn between these companies and the DoD. First is the connection between facility maintenance requirements identification and funds allocation. Each of the five companies researched used a methodical process of identifying the maintenance requirements for their facilities, predominantly relying on equipment manufacturers recommendations and their own expertise. They then constructed a maintenance program that addressed the identified requirements. Funds for these maintenance requirements were based on the documented requirement and included in the annual budget. Corporate financial officers based the facility maintenance budget directly on the identified and documented maintenance requirements.

Similarly, the USAF had a well thought out maintenance identification program in place, one that is comparable to that of most of the companies included in this research effort. Facility maintenance requirements at each installation were based on the equipment manufacturers recommendations and the maintenance professionals'

experience. These requirements were scheduled using computer-based programs that accounted for the labor hours required and supplies needed to perform the task. However, the installations did not forward their maintenance requirements to the MAJCOM. Rather, the FSM program required a detailed description of the facilities at each location and FSM then estimated the annual cost for facility maintenance based on the facility type, construction methods, location unique conditions, etc. At the time of this research effort, the FSM was still in the implementation stage and was not yet being used to allocate funds at any level. Funds for facility maintenance were allocated from The Congress to the Air Staff based on the aggregate installation PV (1.00% of PV.) The Air Staff forwarded those funds to the MAJCOMs and the MAJCOMs to the installations, each adjusting the amount if necessary. In short neither the existing allocation method nor the FSM based methods had a direct correlation between the facility maintenance requirements that had been identified by the installations and the funds they are eventually allocated for the performance of those identified maintenance requirements.

Four of the five companies researched used a methodical process of identifying the maintenance requirements for their facilities, predominantly relying on facility inspections, notification by employees, and/or proactive maintenance techniques such as vibration analysis and thermal imaging. Historical minor repair costs were used as a basis for repair fund allocation. Should that amount not be adequate, procedures were in place to request additional funds. Major repair requirements were well documented and accompanied by a written justification, which detailed how the problem was effecting production. Funds were then allocated based on the identified repair requirement.

In this case, the USAF had a similar process in place. The installation facility maintenance team, through inspections, occupant notification, and proactive maintenance techniques, identified all facility repair requirements. These requirements were then analyzed using the FIM program to categorize the requirement based on mission area (Primary Mission, Mission Support, Base Support, Community Support) and their level of impact (Critical, Degraded, Minimal). However, FIM was not an allocation method and, like maintenance funds, facility repair funds were allocated as a percentage of the plant value (0.75%). Funds for facility repairs were allocated by The Congress to the Air Staff based on the aggregate installation PV (0.75% of PV.) The program was devised so that the Air Staff forwarded those funds to the MAJCOMs and the MAJCOMs to the installations, each apportioning amounts to ensure the most urgent requirements were addressed. Like maintenance requirements fund allocation, there was no connection between the identified repair requirements and the allocation of funds to meet those requirements.

This disconnection of the maintenance and repair requirements from the allocation of funds to meet those requirements generated several persistent problems. First, the disconnect between facility maintenance requirements and fund allocation to meet those requirements lead to under-funding many maintenance programs. Installations made up for this under-funding by shifting O&M funds from other requirements or requiring the organizations using the facilities to provide the necessary funds. The end result of this problem was that the actual maintenance requirement was masked from those providing the funds and accelerated the degradation of the facilities, which lead directly to increased repair costs.

Second, the disconnect between facility repair requirements and the funds allocated to meet those requirements resulted in under-funded repair programs. Facility repair requirements were often deferred until they became critical due to a shortage of funds. In addition, the under-funded maintenance program increased the already inadequately funded repair requirement while repair funding remained unchanged.

At the time of this research effort, the practice of only funding urgent and emergency repair requirements was still in place with the remaining funds reallocated to weapon systems modernization programs. The leaders responsible for this decision were aware of the impact M&R deferral would have on overall facility conditions; however, replacement of obsolescent weapon systems was a high priority. The reallocation of funds was originally only to last for two years; however, it had lasted for five years at the time of this research effort. This practice further exacerbates the problem of increased repair requirements and an increased rate of degradation.

These problems taken together increased the total backlog of repair requirements as well as increased the rate at which that backlog is growing. This backlog is evidenced by accelerated facility degradation and premature facility failure. Facility maintenance professionals are often left with no options for correcting the overall degradation of the facilities for which they are responsible. Once a facility became degraded to the point of no longer meeting the mission requirements, installation facility maintenance professionals often attempted to renovate or replace them through the use of the MILCON appropriation where it would compete with all other military capital investment requirements. The end result is an increase in the number of increasingly degraded

facilities, which impacted the facility occupants mission capability, personnel retention, and ultimately the long term operational and facility costs.

Recommendations

Analysis of the data gathered during this research effort lead to the following recommendations:

Change Perception of the Value of Facility M&R

Although each of the five companies researched placed differing emphasis on facility and infrastructure investment, they each viewed this investment as an important part of their productivity. Facilities were first seen as a means of production and therefore maintained at an acceptable level to minimize the impact to the goods or services being provided. Employee productivity was addressed both in the level of maintenance provided as well as the initial facility design.

Much like private corporations, the US Federal Government has invested a significant monetary amount to provide facilities for the military to operate from. The current plant replacement value for DoD facility and infrastructure investment exceeds $500 Billion. Adequate facility maintenance and repair must be considered a cost of doing business from the beginning and adequately allocated in order to maximize the ability of the military to perform its mission as well as to protect the monetary investment.

Of the five companies researched, one appeared to be in similar circumstances as the USAF: NCR. NCR's past facility maintenance practices resulted in a current inventory of aged facilities that have been poorly maintained. NCR's leadership had identified how their past practices had impacted their ability to remain competitive in their chosen field of endeavor and implemented a strategy to improve the quality of the

workplace provided by their facilities. Their efforts over the past decade to improve the quality of their facilities had been a difficult balancing act between allocating the funds necessary to correct the identified deficiencies and living within a budget that the corporation could afford.

This is in contrast with Dana Corporation. Dana Corporation was committed to maintaining their facilitates in "like-new" condition, both in areas that were readily seen by employees and the public as well as the underlying supporting systems such as mechanical equipment that go "unseen". Yet, Dana Corporation remained the leader in the highly competitive field of providing parts and assemblies to major automotive manufacturers around the world. Their leadership was committed to providing the facility maintenance funds necessary to meet their goals and avoided deferring M&R requirements if possible. The result was a first rate facility that required few repairs or work arounds and was excellent for the work being performed there. Dana Corporation demonstrated that corporate commitment to long-term facility maintenance does not necessarily lead to higher production costs.

Connect Facility M&R Allocation To Identified Requirements

Each of the five companies studied in this research effort used various differing methods to directly correlate their facility M&R allocation to the identified need. The USAF and DoD also correlate the allocation of funds to the identified need at the lowest levels of the organization. However, distribution at the upper levels of the organization still relied heavily on an historical estimate of the requirement based on a pre-set percentage of the plant value.

The implementation of first the CFA and later the FIM resulted in exceptional documentation of the facility and infrastructure repair requirements for each installation within each MAJCOM and, in turn, within the entire USAF. This documentation, in many ways, exceeded the efforts commonly found within private industry. However, total repair allocation by the USAF was based on 0.75% of plant value as opposed to the aggregate of identified requirements and remained significantly less than the investment made by non governmental organizations for facility repair. At best, the MAJCOMs and/or installations used the FIM ratings to categorize the identified requirements and allocate the predetermined funds to the highest priority requirements.

Similarly, the FSM was a refinement of the estimating process for maintenance requirements. Where previous costs were estimated at 1.00% of plant value, FSM estimated the maintenance costs based on the use of the facility, construction method, specialized equipment, etc. However, allocation of funds from USAF to the MAJCOMs for maintenance activities was still based on the real property plant value.

Neither the FIM nor the FSM utilize the information gathered at the installation level for actual maintenance and repair requirements to allocate funds to meet those requirements. Instead, a predetermined percentage was allocated from the USAF to the MAJCOMs.

Most USAF Civil Engineer Squadrons currently manage their real property assets, facility repair projects, and recurring facility maintenance activities using computerized processes. A computerized system could be devised that would allow the actual maintenance and repair cost estimates prepared by the installation to be included in a total USAF facility and infrastructure M&R requirement. This method would use the available

known requirements as the basis for the allocation of funds rather than as a tool to distribute what funds are made available to the most urgent requirements and deferring the rest.

Funding

The primary argument facing the implementation of the recommendations outlined above is the perceived cost. Of the five companies studied, the USAF most closely resembles NCR in that the known requirement seems greater than what is considered to be affordable. Also in parallel with NCR, the USAF arrived at that point by following the practice of M&R deferral over a period of years.

Limitations of the Research Effort

The results from this research effort are valid and supported by the available documentation. As with all research efforts, certain limitations to the scope of effort were purposefully implemented to prevent the required effort from exceeding the abilities of a master's degree research project.

The major limitation of this research effort was the limited amount of time and manpower available to conduct the interviews and perform the analysis. As the effort of a single researcher, a small population of companies to be sampled was all that was feasible given the relatively short amount of time provided for the effort. A team of researchers coupled with adequate time to perform the interviews and analyze the results would be able to provide a breadth of study unavailable under these conditions.

In order to comply with the limitations of time and available manpower, the decision was made to focus the research effort on five companies that were known for excellence within their field of expertise and were within reasonable distance from the

research location (Dayton, Ohio.) For each of those five companies, a site visit was made to one location, either a headquarters campus or manufacturing plan.

Another limitation of this research was the limited variety of companies selected for study. Of the five companies researched, three were in the automotive industry. Two of these are direct competitors: Daimler-Chrysler TNAP produces the Jeep Liberty and General Motors MAP produces the Chevrolet Trail Blazer, both mid-sized sport utility vehicles. Having several companies from the same industry permitted comparisons of different methodologies applied to otherwise similar organizations; however, it presented a drawback in that it limited the overall diversity of the research for a sample size of five companies.

A final limitation is a lack of quantitative data. This research effort relied heavily on interviews with experts from each of the companies and the information they provided. Actual cost data for facility maintenance and repair was considered to be "proprietary information" by several companies and was therefore not pursued.

Despite these limiting factors, the stated goal of this research effort was attained. Five selected successful companies were studied and their facilities M&R requirements identification processes and funds allocation processes were documented.

Areas for Further Research

Additional research of the facility M&R requirements identification and allocation methods used by "for-profit" corporations is warranted. Individuals or teams could perform additional research, to focusing on specific industries such as all paper product companies or all automotive parts suppliers. A focused effort could provide insight into how all of the companies within that particular industry compared and determine if there

are any statistical correlations between the companies profitability and facility M&R programs.

Appendix A: Case Study Protocol

The importance of selecting an appropriate research strategy cannot be over emphasized. In order to select the proper strategy, the type of research questions, the extent of control over behavioral events and the degree of focus on contemporary issues must be analyzed in light of the strengths and weaknesses of the five predominant strategies: Experimentation, Survey Analysis, Archival Analysis, Historical Analysis, and Case Study Analysis.

A multiple case study, which is a cross analysis of several individual case studies, was determined to be the optimal method for conducting this research effort. A case study protocol is developed to guide the researcher through the research process and increases the overall reliability of the case study. Additionally, a case study protocol adds stability in the methods used for each case in a multiple case study and is therefore considered to be the single most important document used during the performance of a case study.

This research effort consisted of five individual case studied which were then correlated into a single cross-case analysis. The following case study protocol was used to guide the research and provided the foundation necessary to ensure that each company was researched and documented using identical techniques.

Overview

Typical Methodologies

Research performed by Gregory Ottoman and others have identified many different methods of identifying maintenance requirements and allocating funds to those requirements. These methods can be placed into one of four broad categories: Plant Value (PV) methodologies, Condition Assessment Technique (CAT) methodologies, Life-Cycle Cost (LCC) methodologies, and Formula Budgeting (FB) methodologies.

The PV method assumes that the maintenance requirements of a given plant can be estimated by the replacement values of the plant. PV is often used on a macro- scale to provide funding for an aggregate of facilities within an established plant.

There are two predominant methods of PV. The first method uses an analysis of what it would cost to acquire a facility with all of the attributes of the existing facility using modern materials and equipment. Current building codes and other regulations that must be complied with are also taken into consideration. The resulting cost is based on established unit cost factors and is an accurate replacement value of a given facility. This is the method preferred by the United States Air Force (USAF).

When unit cost factors are not available, an alternative method is used. The alternative method uses historical records of the original acquisition cost and adjusts that value for inflation, facility improvements, changes in capacity, etc. This allows for a quick and relatively accurate estimate.

The second broad category of methods is CAT. The CAT method is used to program maintenance funds based on the existing condition of the plant.

There are two common CAT methods. The first method determines a budget based on the condition of the facility. Cost estimates for the individual work requirements are then made followed by the performance of the maintenance and/or repair work required. This method is considered to focus on the immediate-needs of the facility and is used mainly for curative work.

The other common CAT method focuses on long-term planning. Under this method, a condition assessment is made to predict the remaining useful life of a given facility. Appropriate funds are then programmed in advance for the future M&R requirements necessary to meet the required life span of the facility.

Sharing similarities with the long-term planning CAT method is the LCC methodology. LCC is based on the assumption that breaking a plant down into its various systems and sub-systems and then applying life expectancy estimates can predict the future M&R costs. Having this knowledge allows for the future work and required budgets to be programmed well in advance. The difference between LCC and the long-term planning CAT method is that LCC focuses on minimizing the entire acquisition, operation, maintenance, repair, and ultimate disposal of a facility. LCC is a true cradle-to-grave cost minimization method.

The final broad category is referred to as FB methods. These methods use combinations of various predetermined facility criteria to arrive at an estimated cost. The variables used range from easily measured criteria such as the heated floor area of a facility to less easily quantified criteria such as the prevailing climate or the effects due to the type of construction used.

USAF Methodologies

During the 1980s, DoD went before congress on multiple occasions to request additional funding to eliminate a growing backlog of facility repair requirements. These requirements were generated by the intentional decisions of senior military leaders to focus what funds were available on weapon system modernization programs.

Convinced of the need, Congress provided additional funds. Despite the additional funding, military leaders continued to report that more was needed. Congress then began inquiring of how the previous funds had been spent to determine the true nature of the requirement and if the previously provided additional funds were used to fulfill true requirements. The GAO reported shortly thereafter that the funds were used appropriately. However, some requirements were viewed as less than mission critical, even though they were accurately described requirements.

In response to this criticism, the USAF developed the Commanders Facility Assessment (CFA) in 1989. CFA was designed to be an identification tool for the requirements needed to adequately carry out the mission. The goal was to determine if the facilities in use met the mission requirements that they housed. Teams consisting of facility maintenance professionals and the using agencies surveyed the condition of the installations' facilities. The facility conditions were then rank ordered by the Base Civil Engineer and then certified by the Wing Commander. This process certified deficiencies as valid requirements and rank ordered them from the least deficient to the most deficient.

Although the CFA did a good job identifying the facility deficiencies as defined, several significant problems were identified shortly after implementation. First, CFA did not take into account the mission served by the facility in light of the overall installation

mission. Given two facilities that were equally deficient, a community support facility would be rank ordered and certified equal to primary mission facility.

A second was the subjectivity of ratings between installations and between Major Commands. No formal training was performed to ensure that personnel located at different installations used the same scale to differentiate a facility that was truly in poor condition from one that needed cosmetic renovation. This resulted in a rank order for each installation that accurately reflected the facility conditions on that installation, but could not be accurately compared between installations. Without standardization across the USAF, the "worst" facility on one installation could have been in better condition that another installations' "best" facility, yet still received immediate attention even though it was not actually the most urgently needed requirement from an Air Force perspective.

The final problem was that the CFA was used in a manner inappropriate for its design. Although not designed as an allocation tool, it eventually was used as one. Funds were placed against facilities that were identified as not meeting the facilities mission requirements with out regard for how that facilities mission integrated with the overall installation or Air Force mission.

Although the CFA rules were accurately applied as directed from the Air Staff, these three problems together created a perception that the CFA was not a credible tool. In order to correct these problems, a new tool was devised: The Facility Investment Metric (FIM).

FIM was established from the outset to correct the above noted problems. First, mission impact was now a critical factor. Facility conditions were objectively rated and placed in one of the three well-defined categories of "Minimal", "Degraded", or

"Critical". They were further broken out into one of four defined mission areas: Primary mission, Mission Support, Base Support, and Community Support.

The original perception of subjectivity was not as easily addressed. Categories were now well defined across the USAF, but not all Major Commands applied them the same. The result was a continued differentiation between installations and commands, although not of the scale seen under the CFA. Once this problem was identified, the Air Staff initiated an annual Integrated Process Team meeting to review ALL "critical" ratings and the supporting justifications. This review is the primary method by which consistency across the Air Force is now managed.

Like CFA, FIM was not an allocation method in and of itself. An allocation method was developed that closely followed the FIM ratings to ensure that mission critical facilities received the lion's share of the funding allocation. However, its implementation was not mandatory and some installations and/or Major Commands chose not to do so.

Overall, the FIM process works well. However, DoD began to recognize a problem not in how the USAF was determining requirements and allocating funds, but in how each service differed from one another in methodology and terminology. When faced with making allocation decisions between the services, senior decision makers were often faced with standards that were not comparable. They needed the ability to easily determine where the facility deficiencies were impacting the mission in all branches to ensure that funds were then allocated to the most urgent requirement as seen from the DoD perspective.

To meet this new requirement, DoD implemented the Facility Sustainment Model (FSM) in the Spring of 2000. The FSM was applied across all branches of the DoD,

implementing standardization in terminology and cost estimation techniques. This was done by employing conventional standards found in the facility construction and maintenance professions.

FSM is a requirements identifier that does not consider the age or condition of a facility. Rather, it stipulates the expected maintenance cost for a facility given the type of structure, it's size, and intended use. Facility restoration and re-capitalization costs are not addressed at this time; only the sustainment and replacement construction costs are identified. Future editions of this model are intended to address restoration requirements.

FSM is not without problems. One problem that has been identified is that some unique military facilities do not fit the "standard" model. An example of this would be a large wind tunnel. The standard model is a small facility that houses a portable or small permanently installed device. However, several USAF wind tunnels incorporate purpose-built laboratories with highly specialized aerodynamic and propulsion tunnels, rocket and turbine engine test cells, space environmental chambers, arc heaters, ballistic ranges and other highly specialized facilities. With such a broad range of wind tunnels types, a single category and average maintenance cost estimate is unreasonable. The FSM development and implementation teams are currently addressing this problem and others similar to it.

Project Objectives

The preceding sections presented the four major categories requirement identification and funds allocation methodologies. This was followed by a presentation of how DoD has operated over the years. During the literature review of this subject, it became obvious that there is a lack of information of how civilian companies identify their maintenance requirements, allocate funds to maintenance requirements, and if there is a

conscious effort to tie the former with the latter. In light of this discovery, several objectives for this research have been developed.

The first objective is to determine how companies who have a reputation for exceptional facility investment programs determine their maintenance and repair requirements in comparison to the above outlined four broad categories. The second objective is to evaluate how those same companies then determine the funding amount to allocate to those maintenance and repair requirements. Finally, a comparison of how these methods compare with those of the USAF will be made.

Case Study Issues

In preparing for this research effort, the methods used by facility maintenance professionals were studied in order to establish how work requirements and funding allocations were typically made. Additionally, the methods used by the USAF and DoD were also explored and documented to form a baseline for later comparisons. In order to completely define the direction of this research, several other issues must first be presented.

The first issue is the definition of what qualifies as an exceptional facility investment program. For the purposes of this research, an exceptional facility investment program is defined as any program that defines a desired facility condition level, analyzes the condition of their facility inventory, and allocates funds to maintain their facilities at the specified condition level. This is more than just recognition that a place of employment must occasionally get a new coat of paint. Rather, an exceptional facility investment program formally develops a strategy for facility maintenance that balances the

cost of maintenance with the benefits those facilities provide. Those benefits can be any tangible or intangible quality perceived as desirable by the organization.

Another issue is how the study will be carried out. For this research effort, a pool of candidates will be assembled from a compilation of companies identified as potentially having an exceptional facility investment program by professional facility maintenance organizations. This initial pool includes Fortune 500 companies, companies identified by facilities maintenance professional organizations such as the International Facilities Maintenance Association (IFMA), the Association of Facilities Engineers (AFE) and the Society of American Military Engineers (SAME). This pool of potential candidates will then be examined for similarities to the USAF organizational size, physical plant size, plant dispersion, etc. to reduce the number of candidates to a reasonable number. Candidate companies that indicate similarity to the USAF in organizational, technological, or physical plant demographics will then be approached for further investigation. Companies that accept the invitation will become the basis for individual case studies. Each individual case study will compare and contrast the practices of the interviewed company with the USAF. Upon completion of the individual case studies, a cross case analysis will be performed. The final result of this research will be a multiple case study that presents current industry best practices.

Relevant readings

Additional information and details concerning this research can be found in the documents listed below. Each is available through DTIC and/or the Government Printing Office.

U.S. Department of Defense. Renewing the Built Environment: Real Property Maintenance Activities. Department of Defense Report to Congress, 16

March 1989.

Ottoman, Gregory R., W. Brent Nixon, Steven T. Lofgren. Budgeting For Facility Maintenance and Repair. I: Methods and Models, *Journal of Management in Engineering*, July/August 1999 (71-83).

Ottoman, Gregory R., W. Brent Nixon, Steven T. Lofgren. Budgeting For Facility Maintenance and Repair. II: Multicriteria Process for Model Selection, *Journal of Management in Engineering*, July/August 1999 (84-95).

HQ United States Air Force. Air Force Facility Investment Metric: Implementation & Operations Guide, 1 August 1999

U.S. Department of Defense. DoD Facilities Cost Factors Handbook, Version 2.0, April 2000

The Civil Engineer, HQ United States Air Force. Background Paper on Air Force Facility Investment Strategy. Pentagon, Washington D.C., Undated

Useem, Jerry. Welcome To The New Company Town, *Fortune Magazine*, Vol. 141, No. 1, January 10, 2000

HQ United States Air Force. Air Force Vision 2020, Pentagon, Washington D.C., Undated

Field Procedures

The following section provides the necessary information to ensure the fieldwork is thorough at each site as well as consistent between the sites. The first section delineates the credentials that will be used to establish initial contact with each of the candidate companies. This is followed by identification of the general sources of information used. The final part of this section lists the procedures that will be followed at each site.

Credentials and Access

- Initial contact with representatives of candidate companies will be via telephone.
- A letter of introduction will be sent to each site introducing the researcher. Accompanying this letter will be an advance copy of the questions to be presented during the interview.

General Sources of Information

- Documents provided by company representatives
- Interviews with company representatives

Procedural Reminders

- Goal is to minimize any influence of the researcher on the process.
- Record each interview on tape for later transcription.
- Ensure all documentation provided is noted with company name and date of acceptance.

Case Study Questions

The following section provides questions to be used at each site. The intent is to focus on the methods that companies that are known for high quality facility maintenance programs use for determining their facility maintenance requirements and how they then allocate the necessary funds to meet that requirement.

Topic 1: Maintenance Requirements Identification

1. Do you have any documentation that illustrates how your company is organized and how the facility maintenance section fits into that organizational structure that I may take with me?
2. Can you explain to me how your organization determines the maintenance requirements for your facilities?
3. Can you explain to me what goals your company decision makers had in mind when setting up this method of determining maintenance requirements?
4. What other methods has your company tried prior to implementing this method for determine the maintenance requirements for your facilities?
5. Can you explain to me how your company differentiates between restoration (i.e., repair) and sustainment (i.e., maintenance) requirements?

6. What level of in-house maintenance capability does your organization have and what role do they play?

Topics2: Maintenance Funds Allocation Methods

1. How does your organization determine the amount of funds to be allocated for the maintenance requirements identified?

2. How does your organization allocate funds?

3. Does your company take into account the re-capitalization rate (i.e., length of time required to replace existing facilities at the current rate of investment) of your plant infrastructure when deciding an appropriate allocation rate?

4. How do your customers (i.e., senior management, internal employees, and non-employee visitors) feel about the level of quality to which you maintain your facilities?

   4.1. Have any comments been made concerning the acceptableness of the environment you maintain?

   4.2. Can you explain to me any formal or informal methods for customer feedback that you have in place?

   4.3. What impact does the perception of the facility condition by the employees working in that facility have on your allocation rate?

Analysis Plan and Case Study Reports

The end result of this case study will be a thesis defense presented to the faculty of the Air Force Institute of Technology. Individual case study reports will be prepared for each company that participates and will include a general outline of the goals of the research, a synopsis of the interviews made with that company, and a conclusion section that describes the methods used by the company and compares it to similar methods outlined in Ottomans "Budgeting for Facility Maintenance and Repair". The individual case study reports will be made available to the individual company and the thesis committee. The utmost care will be made to prevent the individual study from becoming

available to anyone other than representatives from the company studied or members of the thesis committee.

This data will then be used to present a thesis defense to the AFIT Faculty. This thesis will be a multiple case study report and will follow the format requirements of the Style Guide for AFIT Theses and Dissertations. The privacy of the companies participating in the study will be protected to the extent of eliminating their names from the reports if that is their preference.

Data Analysis Strategy:

1. Analyze each company's maintenance requirement identification method to that used by the USAF

    1.1. Categorize in one of the four broad facility maintenance categories (PV, CAT, LCC, FB)

    1.2. Identify significant differences with the general category concepts

    1.3. Compare and contrast the company with the USAF

2. Analyze each company's maintenance funding allocation method to that used by the USAF

    2.1. Categorize in one of the four broad facility maintenance categories (PV, CAT, LCC, FB)

    2.2. Identify significant differences with the general category concepts

    2.3. Compare and contrast the company with the USAF

3. Analyze how the company's requirements identification phase is integrated into their fund allocation phase, then compare and contrast the company's methods with the USAF.

4. Compare and contrast each company's view of restoration vs. sustainment as it is applied to requirements identification and funds allocation

5. Analyze each company's view of re-capitalization

Case Study Report

The case study report for each company will consist of a brief introduction of the general aspects of the company. Information included in the formal report shall include the following:

1. A brief description of the goods or services each company provides
2. The relative size of the company in comparison with the industry of which they are a part
3. The company's stated standards for facility maintenance
4. A comparison of each company's maintenance requirement identification method to that used by the USAF
    - 4.1. Categorize in one of the four broad facility maintenance categories (PV, CAT, LCC, FB)
    - 4.2. Identify significant differences with the general category concepts
    - 4.3. Compare and contrast the company with the USAF
5. A comparison of each company's maintenance funding allocation method to that used by the USAF
    - 5.1. Categorize in one of the four broad facility maintenance categories (PV, CAT, LCC, FB)
    - 5.2. Identify significant differences with the general category concepts
    - 5.3. Compare and contrast the company with the USAF
6. Compare and contrast how companies identify requirements vs. allocate funding to those requirements
7. A comparison of each company's view of restoration vs. sustainment as it is applied to requirements identification and funds allocation to that used by the USAF
8. A comparison of each company's view of re-capitalization to that used by the USAF

Appendix B: Potential Contact List

The following list of companies were initially considered for inclusion in this research effort. Factors such as a companies reputation for quality facility maintenance, the physical dispersion of facilities within the corporations real property inventory, the overall size of the physical plant, and locations easily accessible from the Dayton, Ohio, local area were all taken into consideration prior to selecting the final five companies researched.

A K Steel Holding
703 Curtis St.
Middletown, OH 45043
Phone: 513-425-5000

American Electric Power
1 Riverside Plaza
Columbus, OH 43215-2373
Phone: 614-223-1000

American Financial Group
1 E. 4th St.
Cincinnati, OH 45202
Phone: 513-579-2121

AMR Corporation
4333 Amon Carter Blvd.
Fort Worth, TX 76155
Phone: 817-963-1234

BFGoodrich Company
Four Coliseum Center,
2730 W. Tyvola Rd.
Charlotte, NC 28217-4578
Phone: 704-423-7000

Boeing
7755 E. Marginal Way South
Seattle, WA 98108
Phone: 206-655-2121

Cinergy
139 East Fourth Street
Cincinnati, OH 45202
Phone: 513-287-1099

Consolidated Stores
300 Phillipi Rd.
Columbus, OH 43228-0512
Phone: 614-278-6800

Continental Airlines, Inc.
1600 Smith St., Dept. HQSEO
Houston, TX 77002
Phone: 713-324-5000

Daimler-Chrysler Corporation
Auburn Hills, MI 48326-2766
Phone: 248-576-5741

Dana Corporation
4500 Dorr St.
Toledo, OH 43615
419-535-4500

Delphi Automotive Systems Corp
5725 Delphi Dr.
Troy, MI 48098-2815
Phone: 248-813-2000

Delta Air Lines, Inc.
Hartsfield Atlanta International Airport
Atlanta, GA 30320
Phone: 404-715-2600

Eaton Corporation
Eaton Center
1111 Superior Ave.
Cleveland, OH 44114-2584
Phone: 216-523-5000

Federal-Mogul Corporation
26555 Northwestern Hwy.
Southfield, MI 48034
Phone: 248-354-7700

Federated Department Stores, Inc.
7 W. 7th St.
Cincinnati, OH 45202
Phone: 513-579-7000

Fifth Third Bancorp
38 Fountain Square Plaza
Cincinnati, OH 45263
Phone: 513-579-5300

Ford Motor Company
One American Rd.
Dearborn, MI 48126-2798
Phone: 313-322-3000

General Dynamics Corporation
3190 Fairview Park Dr.
Falls Church, VA 22042-4523
Phone: 703-876-3000

General Electric Company
3135 Easton Tpke.
Fairfield, CT 06431-0001
Phone: 203-373-2211

General Motors Corporation
300 Renaissance Center
Detroit, MI 48265
Phone: 313-556-5000

Goodyear Tire & Rubber Co.
1144 E. Market St.
Akron, OH 44316
Phone: 330-796-2121

Honeywell International Inc.
101 Columbia Rd. PO Box 2245
Morristown, NJ 07962-2245
Phone: 973-455-2000

Kroger Co.
1014 Vine St.
Cincinnati, OH 45202
Phone: 513-762-4000

Lockheed Martin Corporation
6801 Rockledge Dr.
Bethesda, MD 20817
Phone: 301-897-6000

LTV Corporation
200 Public Sq.
Cleveland, OH 44114-2308
Phone: 216-622-5000

Mead Corporation
Courthouse Plaza N.E.,
Dayton, OH 45463
937-495-6323

Merck & Co., Inc.
1 Merck Dr.
Whitehouse Station, NJ 08889-0100
Phone: 908-423-1000

Nationwide
One Nationwide Plaza
Columbus, OH 43215-2220
Phone: 614-249-7111

Navistar International Corporation
455 N. Cityfront Plaza Dr.
Chicago, IL 60611
Phone: 312-836-2000

NCR Corporation
1700 S. Patterson Blvd.
Dayton, OH 45479
Phone: 937-445-5000

Northrop Grumman Corporation
1840 Century Park East
Los Angeles, CA 90067-2199
Phone: 310-553-6262

Northwest Airlines Corporation
5101 Northwest Dr.
St. Paul, MN 55121-3034
Phone: 612-726-2111

OfficeMax, Inc.
3605 Warrensville Center Rd.
Shaker Heights, OH 44122
Phone: 216-921-6900

Owens Corning
One Owens Corning Pkwy.
Toledo, OH 43659
Phone: 419-248-8000

Parker Hannifin Corporation
6035 Parkland Blvd.
Cleveland, OH 44124-4141
Phone: 216-896-3000

Precision Castparts Corp.
4650 SW Macadam Ave., Ste. 440
Portland, OR 97201-4254
Phone: 503-417-4800

Procter & Gamble
1 P&G Plaza;
Cincinnati, OH 45202
513-983-1100

Pyramid Services, Inc.
2501 East Avenue P
Palmdale, CA 9.3550
661-272-6660

Sequa Corporation
200 Park Ave.
New York, NY 10166
Phone: 212-986-5500

Textron Inc.
40 Westminster St.
Providence, RI 02903-2596
Phone: 401-421-2800

TRW Inc.
1900 Richmond Rd.
Cleveland, OH 44124-2760
Phone: 216-291-7000

UAL Corporation
1200 E. Algonquin Rd.
Elk Grove Township, IL 60007
Phone: 847-700-4000

United Technologies Corporation
One Financial Plaza
Hartford, CT 06103
Phone: 860-728-7000

Appendix C: Interview Transcripts

Following is an edited transcript of the interviews conducted by the researcher and representatives of the five companies utilized in this effort. Those five companies were Daimler-Chrysler AG, Dana Corporation, General Motors Corporation, Mead Corporation, and NCR Corporation. Each interview was conducted at the employees' business location and transcription was aided through the use of tape recordings.

The transcriptions are presented in alphabetical order of their companies name and have no bearing on the opinions or bias of the researcher, the Air Force Institute of Technology, the US Air Force, or the Department of Defense.

Daimler-Chrysler AG

Interview Date: 09 May 2001

Location: Toledo North Assembly Plant (TNAP), Toledo, Ohio

The following is a transcript of a discussion of D-C benchmarking and documentation for the construction of TNAP beginning in 1998. Facility construction took 12 months, plus an additional year to install equipment. TNAP became operational in January 2001. The primary purpose is the assembly of D-C Jeep Liberty and final assembly of D-C Jeep Wrangler vehicles.

TNAP ELECTRICIAN A: : I'm an electrician with Daimler-Chrysler for over 16 years now. Originally, there were 40 something skilled tradesmen involved with this benchmarking process to look at best practices both inside the corporation and outside the corporation to try to find the pockets of things that were working. One of our goals was to increase the efficiency of first response and general maintenance of the plant. Of course, mean-time-to-fail and mean-time-to-repair, keeping those things in mind, quick response teams. Some of us, but not all of us, got to look at the military, Disney World, Delta Airlines, and an auto plant - I think Toyota – but they didn't want us in there. We looked at pit crews of Dodge Truck racing, and they did get to go up to a CART race up in Detroit, the Detroit Grand Prix, where they got to look at how a couple of pit crews operated up there. Again, they went out to the military, they went out to San Diego to the US Constellation. Mainly, they looked at the bearing vibration analysis which we ended up purchasing software. We're monitoring bearings, fan blades, and higher-speed applications for failure tracking. Of the 40 guys, we figured we had over 3000 hour-years

of experience. So, we tried to pool those resources. We broke up into groups to decide what were the main problem areas in the maintenance program of our existing system, what did we want to do as a group to increase the efficiency or help ourselves in this plant. That was the challenge.

We really had no direction from our bosses other than to work on ideas that we could come up with to do our job better in the future. And then try to set up those policies and practices. It was all on a voluntary basis.

RESEARCHER: How did you document your work?

FACILITY MANAGER: Do you want to answer that?

TNAP ELECTRICIAN B: Yeah. My name is Jim Fletcher. I'm an electrician with 26 years of work experience. The teams that Jeff was referring to earlier were brainstorming sessions. Brainstorming meaning that you could throw out any idea that came into your head that was subject related. We wrote them down on a board. Regardless of where the idea went, as long as it pertained to the subject matter, we wrote down all the ideas. We then came back afterwards and determined which ideas were practical. That's how we honed down what we saw, as a group with many years of experience, as the best ways of doing things. From our standpoint – the guys on the floor, who are doing the maintenance – To arrive at the position we wanted. For us to be able to do our jobs. For us to have information. For us to be straight minded on how we're going to get our parts. For us to be able to get information and documentation that we need to continue to maintain the plant. Those were the areas that we all looked at, we all threw out ideas. How did we get there? We just all brain stormed and compiled lists and worked on that list.

RESEARCHER: It sounds like you had two different tasks. An in-house brainstorming session and also benchmarking other facilities.

TNAP ELECTRICIAN A: : We looked at other facilities, looked for other ideas, things that were working in other areas or other companies. We had ideas of our own; one, to improve our job was to get spare parts into our hands and, two, tools. Having tools on hand for all of the trades. In the past, in our old building, 1) because of the size of the building, there were locations all over the building, there was no central location for materials or work parts. So, one of the things we focused in on in our three buildings here is a central location for parts and a central location for tools, which is right behind you. Then we looked at ways to track those tools, how to store parts, and how to disperse them. We found a couple areas. One was in Auburn Hills where they were using a program called "Tool Watch", which was just a simple database that uses a barcode scanner. You put the bar code on the tools and check them in and out using a card like a library card. We looked at that, saw that it was working, and then compared it to one other software package out there called "Red Oak." We found that this ("Tool Watch") was the easiest to use and less expensive.

FACILITY MANAGER: To give some clarity to what Jim was telling you about, that was probably the beginning, the brainstorming and the writing down a list of things. The benchmarking came later, after it was categorized. To say, "Ok, here are all the things that we came up with to look at." Then they put champions to each of those things. "OK, Jim, you're the champion of this category." And as those things got categorized, then Jim could decide to go look at Delta Airlines to see how they do what I'm championing. For example, if it's vibration analysis, then he'd set up a trip to go here

or go there and look at that. Jeff might have been the champion for how we take tools, control the access to them, and track who has them. So he may have been the guy who went out and benchmarked the methodology for doing that. Then other people did the same thing, finding the best application here. It kind of came in steps, it wasn't one guy going off and doing one thing while another guy went off and did another. It occurred chronologically.

FACILITY MANAGER: We also tried to get members of each trade to go and look at the same information, to look at it from two or three different angles.

TNAP ELECTRICIAN B: You need to have all the trades involved because the decisions effect all trades. That's kind of how we got to where we are, we had input from all of the trades. So, if a tool maker had an issue that we could incorporate into our concerns or an electrician had an issue about something over here, alright. Each team that went out did not go out as an all electrician group or an all maintenance group, we wanted a team, a hodge-podge of different trades. Then they came back and debriefed, wrote reports about what they saw. Then they were always called upon to give their opinions. The information was dispersed

RESEARCHER: When you published your report, whom did it go to? Who was in charge of making decisions?

TNAP ELECTRICIAN A: : We pre4tty much handled our own information, stored it , and brought it up as the thought process developed. We picked certain ideas, again, we gave our input on… "here's what we found here, and here's what we found there." And then they reviewed with us, management groups.

FACILITY MANAGER: Obviously, we have to take that information forward for funding, approval, things like that. So they would come back and tell us, " OK, here's who you went to see." We'd given them the guidance. We told them, "Here are the parameters that you have to work within." Budget constraints, capital equipment constraints, whatever that might be, space constraints, things of that nature. We gave them the parameters that they had to work with. So they already had a good feel for… Knowing the constraints, here's what we've come back with that fits the constraints and can best do the job. The task became easy at that point because then it was just… If it's within the parameters, your happy with it, being what you like the best, then it would happen. So, that's kind of the methodology that we used.

RESEARCHER: At what level were the decisions being made? Did you have to defend it before a "murder board" of corporate gurus or was there somebody more down on this level (shop level) that said, "Yeah, we can spend this much money on, say, bar-code reading machines?"

FACILITY MANAGER: It was down here on this level.

RESEARCHER: Did they give you a budget for what you could spend?

TNAP ELECTRICIAN A: : Yeah. What we do is we write a project and in that project we put line items, budget dollar figures for those line items. So that's per the constraints that we talked about. We told these guys "We've got a line item that supports this much, so don't come back with a $1,000,000 machine on a $2,000 budget because the odds of getting approval would be slim to none." We do have the ability to fluctuate some of those dollars, but the only fluctuation you have is, well, this line item has $1,000,000 but we only needed $800,000 so we've got a couple hundred thousand available that we

can shuffle into another line item. You can only under-run one and over run another, within reason. But, like I said, if everybody that had a line item comes back with a million dollar item for a $2,000 line item, obviously we'll all over-run. So, we have that fluctuation-ability with in the project, but within those guidelines.

That's way, way back in the project for this plant. What they did was, within the project of building this facility and building this car… I mean, it was a large project, $750,000 project that went in to pay for the facility, for the car, for that computer, and that ladder. It went for everything from that ladder to the engineering of this vehicle. And that was all broken down into smaller projects that do those individual things and those projects were broken down into those line items that I talked about, the dollar figures and budgetary items. We don't really have a line item that's called "ladders and carts". It may say "body shop facility." So, that line item may be $500,000 strong, but that item pays for everything including the tools. So, when you start doing that, you have to take all that into account. You can't go out and buy all that cabinetry and then find out that you can't afford to tools for the drawers. That's the kind of things that these guys, who knew those constraints… They knew enough not to spend all of our money on silverware and then not be able to eat anything with it because you can't buy the food. So, yeah, they had that information. That's kind of how it comes to be.

FACILITY MANAGER: We were asked to come up with a wish list of everything that we thought we would need to run this plant. And I would say that we got probably 60% of what we asked for. But, we also realized that a lot of the items may not be needed for several years as things break down. Those things will come from later budgets.

We had three groups for preventative maintenance, looking at the way the equipment was coming in and how we were supposed to repair it and maintain it. We also had a group that went out to the build shops on a regular basis and looked at it from a reparability point of view. We were talking a lot about standardization. We had some input, not a lot of input. So we had repair parts were more standardized instead of multiple brands that were not interchangeable. This has been one of the best projects that I've seen where they did standardize.

TNAP ELECTRICIAN B: Let me give you an example. It's a good one for us because we have to deal with it all the time. The cylinders that we use to move things with, hydraulic cylinders, they have switches on them. They're called "Cylindicators." And they indicate whether the cylinder is fully extended or fully retracted. Our vendor originally installed a cylindicator with a pig-tail lead that you plugged into another pig-tail lead that plugged into back of the unit. Now that required two different switches. Same application, two different switches. We had to carry both in stores. We looked at it and decided that it was no good. We went back to the vendor and told him to provide us with two switches that were the same. Now we only have to carry one style switch and one adapter that fits everything. We eliminated the requirement to carry one extra switch. So we reduced our requirement by one-half for all the cylidicators that we had to buy because now we only needed one style. That's just one of the things, among several others, that we looked at and said, "We should not have that, we should have this instead." This equates to a couple of different things. Not only do we reduce inventory, but also the probability of not having what you need when you need it. If you have a common component, it's easier to find one of those or rob it off of something and make it work

than trying to find the "left-handed one." We've got a hundred left-handed ones, but where's that left-handed one? There's where you now have availability. Which is time. That time is money, too. The amount of time that this guy spends running around finding that component is also money. So, these are some of the things that these guys were interested in.

RESEARCHER: When you were specifying equipment, were you able to dictate name-brand items? For instance, a Simplex® fire alarm panel, model such and so….

TNAP ELECTRICIAN B: Those were called out in a company standard. The contractor was told "These are the parts that you can use." They were called out by brand and listed. And even though the part was listed, we could still say, "No, we don't want to use that one. Use this standard one so we have one connector style instead of two." That's just one example of the many, many things that we looked at and said "let's not do that."

We understand that sometimes you have a hundred of these and one of those and when you need one of those, it's gone. If they're all the same then you're more likely to have what you need on hand when you need it. Those are the kinds of things that the experience, the knowledge gained from being on the job for years, allows you to notice right away that "why is that different from that?" when we only need one.

Another thing that I can bring up is that the drives for the (vehicle conveyer) lines out here. Originally, they were called out with individual specs for each line, each motor so large and so forth. We have three of them, why do we have three different sizes? Let's make them all the same and then we only need to keep one spare on hand. Even though it may cost more to acquire a motor that is actually larger than what is needed, we save on

having only one spare on hand instead of three. When they cost $250,000 a piece, you don't want to buy too many of them.

TNAP ELECTRICIAN A: : The A&E from Chrysler Engineering Group was looking at things the same way prior to us getting involved. We looked at it from a repair-ability stance also as far as access to things. "Can we get to that panel? Can we get to that drive? What do we need to get up there quickly so that we can change things if it does break down?" This was a component of the things that we did that made a difference.

TNAP ELECTRICIAN B: If you look out on the line, you'll notice that there are areas where it is almost impossible to get to a piece of equipment. As we looked at the plant, looked at the plans, and looked at the machinery and then related that to our problems, if this thing stops out here, we've got no piece of machinery that can go out there and get it. We have to have a rail over the top of it. So, we got a hold of management and sat down with engineering and told that that it won't work; if this thing breaks, there's no way we can get in there to it. Overhead rails and things of that nature that weren't originally on the specs were things that we looked at.

I'll give you another example. There are large elevators out here called material handling units for handling pallets. They weigh about 3000 pounds apiece. There is a platform that allows you to reach the drive that is located on top. But below that platform, there are switches that give the position of the lift. Well, there was originally no way to reach those switches. I watched the contractors lay on the deck, reach down and dangle in mid-air to set those switches. I took one look at that and said, "We can not do that while we're running." So we came back and had them build platforms down just so we could get to the switches. We knew that if they went bad, there was no way to get to those

switches. As the plant was going up and we could see that this was a problem here, we knew that it would fail after so many strokes. It may fail at three o'clock in the afternoon or at three in the morning. But it is going to eventually fail and when it does, it's going to be hell getting to it. We looked at a lot of things in that respect. How do we get to it, how do we service it, what has to be done for us to be able to service it safely.

Another example is the decks for the pallet line out here on the underbody line. Because of the position and complication of the machinery – you have robots on both sides of the line – there are walkways built in where you press a button, the machine stops and you can walk through. Underbody has none. There's a cage, you open a gate and go down. How do I get from this side to the other side in a relatively short amount of time without having to walk all the way down to the end of the plant, turn around, and walk all the way back just to get on the other side of this piece of machinery? We installed walk-overs. It saves time for us so that we don't have to shut the line down or walk around to gain access to that spot. It's a long haul to go all-the-way down and all-the-way back. It's much simpler to step across. It's little things like that that have helped out a lot.

FACILITY MANAGER: One of the questions that you have on your thing (protocol) that I suspect these guys could answer, "What level of in-house capability does your organization have?" I know they've been kind of talking about this a little bit but I don't know if there were any other tasks that you might want to talk about.

Rather than just hearing it from me, it certainly helps hearing it and – perhaps at a more detailed level – from the guys who do it. And I'm guessing that the military has different levels within the organizations for M&R. Here, we don't have the same structure , but we do kind of do things the same way from the point of view that these guys may

change a motor out but they don't bring it back here and re-wind it. They send it out to some place to have that done.

RESEARCHER: How big is your in-house staff?

FACILITY MANAGER: In this shop, we've got 38 men per shift. Total within the entire plant there's 321 maintenance personnel in the assembly shop, the paint shop, and the body shop.

RESEARCHER: What are you responsible for? The equipment? The equipment and facility?

TNAP ELECTRICIAN B: We call these areas "decks". Right now, we're in the main maintenance deck. This is the control room, where we monitor what's going on out there. And then there are satellite decks in each manufacturing area of the plant. Underbody, they have a deck. It's a smaller maintenance area where the guy's hang out, where the (control) box's are. It's the area where they can look and see what's going on out on the floor. They can see the bingo boards, which are the panel of lights that tell them what's up, what's down. They look at the screens to see what the machine status are. Each one of the areas has a deck like that. So, those are manned with all the trades. We have satellite decks where the guy's respond to the needs of the area, the machinery and tools. Out of the main deck we do the facility and back up the satellite decks. So if it's a heater, or air compressor, or general lighting, or power, or a water leak, we take care of the facility here and back up the needs of the satellite decks. And, we do the spare parts ordering.

RESEARCHER: You mentioned contracting out the motor rewinding. What other types of jobs do you send out to a contractor or have a contractor come in for you as opposed to doing it with your in-house work force?

FACILITY MANAGER: Some of those things are decisions that are made based on… They're business decisions. For example, repairing the roof. We may have 12 roof leaks a year due to some reason or other. Say, an ice sickle falls off of a vent stack puncturing the roof and we need someone to come out. Rather than using the in-house staff to do that, we'll hire a contractor to come in and do those few patches rather than using an employee. The investment in an employee is like $8,000,000. That's the corporations latest numbers. Once you hire someone, you've just spent $800,000 between the benefits, training, the life-long commitment to the employee. So with that in mind, it's much easier to bring in a contractor for a few bucks and say "Thanks, we appreciate you being here," but haven't invested any money in an employee. We've only spent a few grand. The same thing with some of the services.

For the most part, the guy's here are capable of doing anything that someone on the outside is capable of doing. It's really just a manner of how much do you want to invest in someone for them to do the job. If we're going to have a piece of capital equipment that's going to sit idle for 11-months out of the year. Perhaps not 11 consecutive months, but when you boil it down to how often you're repairing something that utilizes that special equipment to do it; if it's going to sit idle for 11-months out of the year, then it doesn't make sense to make that capital investment to make that repair when you can do it with someone on the outside who is repairing those same components from not only our assembly plant but from twelve others so that twelve months out of the year

he's using that piece of equipment, completely utilizing it so that we're not making that investment.

Those are the kinds of things that make part of that decision for us. And then some of it is because of the specialization of the equipment. The robots out here all come from Japan, they're Nachi® robots, and you won't find us rebuilding the servos or motors in those things. Typically, we send those back or only exchange replacement parts. Allen Bradley® drives, it's the same thing. We don't do component level repairs, we send the unit back to a depot repair center where they have all of the specialized test equipment that wouldn't be cost effective for us to have. They're servicing many different customers, bringing it all into on rebuilding facility so it's cost effective for them to do that and have that equipment on hand.

That would be like us building a plant to manufacture six cars a day. It wouldn't be worth it, we'd lose money and couldn't stay in business. It's the same sort of thing.

TNAP ELECTRICIAN A: : The industry is changing, to more plug-n-play components. Most things aren't repairable, it's cheaper to replace them. And then we write it down on our red warranty table. That's another thing we're trying to do, track warranty items.

RESEARCHER: The reason that I brought that question up is that, with in the military, there is a large thrust to out-source facility maintenance, with the exception of real military requirements. For example, when a fighter wing deploys, facility maintenance teams deploy with them to maintain the facilities that they live in and so forth. However, at someplace like Randolph AFB, where they do pilot training, there is no real military requirement to have military facility maintenance people. So, they're

outsourcing it, hiring contractors to come in and do all of the work for us. The reason I brought the question up is to determine why Daimler-Chrysler continued to do the work in-house rather than outsourcing to a private contractor that specializes in doing facility M&R.

FACILITY MANAGER: Quite honestly, there are some facility maintenance things that we hire contractors for. For example, grounds maintenance. We hire a service contractor to do that. Like I said, roof repairs, we typically bring in a contractor for that. All of our paving is done on the outside (by contractors). Door repair, over head doors. Depending on how extensive it is. These guy's (in-house maintenance crew) will get a call that a door isn't opening or closing. They'll walk out and see that somebody ran into the conduit and pinched the wire. They'll straighten it out and splice the wire back together. So, they'll take care of that. They are the first responders to just about everything. But, they will go out and take a look at it and they've got to the point where they know that this is either within or beyond their capability or take away from their other jobs. Their main focus is maintaining the production equipment. That's what really pay's our bills, moving cars off the end of the line. So they know that's their focus. They'll look at it and decide that they can either spend 8-hours trying to fix something but while they're doing that there will be machinery that won't be running. At that point in time, we'll take a look at it and decide whether or not to call in a contractor to come in and fix it. Again, it's the investment. At what point in time do we decide whether we should hire six more guys to sit and wait for those things to happen and invest $8,000,000 a pop or do we say, no, you guy's keep working on the line and we'll bring in a contractor for a few hours and spend perhaps a few thousand. It becomes a balancing thing. If this plant

had 3,000 doors and we could keep two guys busy all day just doing doors, then we'd hire them because it would be cheaper for us to do that. But we don't have that, we have two guys who work on doors and, oh by the way, they also work on line equipment. What ends up happening is the line equipment takes precedence so the doors are going to have to suffer. It's a simple thing. We find it to be even the simplest things. Even the lights over the boss' desk. Those don't keep the car being built. You get to the point where you say, "Well, these guys get busy on building cars, so some things have to suffer. That light might not get changed for a week because the focus is on building the car. And that's one of the things that we used as an example from the Jefferson Street plant. They had that happen to them, things were just let go because their focus was on building cars. Talking with those guys at the Jefferson plant, they said that after about five years they had to put on a crew of about eight guys to go and take care of the things that had been left. It wasn't enough to bring someone in from the outside to take care of it and it was not a priority because they were busy working on the equipment for building the cars. You have to weigh what makes good business since, what do you do and how do you do it. That's kind of a concept, a recurring battle almost, a recurring process that goes on.

RESEARCHER: Do you have any specific techniques that you use for identifying maintenance or repair requirements? Inspections?

TNAP ELECTRICIAN B: There is a regular PM program that generates that. It's called TMS, Total Maintenance System. It cranks out… Each employee in the maintenance area has a specific number, a T-number, that the system uses. You can actually get on line, enter your T-number, and see what specific tasks you need to be doing to cover the PM. Either a visual inspection or take the torque on something or

physically go out and tighten all the screws on that panel. Those that come up as our system calls them out, it automatically calls out the requirement. For instance, if I come in on Saturday, I'll enter my T-number, it will have a list of functions or things that I need to do that day. As I do them, I buy them off. And then I have provisions on that format that I can add notes such as I found something that needs attention. As those are reviewed, they'll generate a work order to have that repaired.

So, yes, there is an ongoing system, it's call the in-house preventive maintenance system, a part of our PM system. All of us maintenance guys have access to it. And that was generated… Well, it was a program that we got from one of our vendors, a tool manufacturer, building facility people, or anyone that has something to do with the equipment in this plant. They submitted their PM list to us. We looked at them and cleaned them. For example, one of the shops wanted us to do a certain activity once a week. We never do that, better look at it only once a month. Realistically, we went through it and gleaned out all of the fluffy stuff. We realized that we would never be able to get to all of this stuff, it would be never ending. So we took out the ones that we knew that we'd have to do to maintain the equipment, to meet the warranty, we put them in our TMS system and those are the ones that we'll refer to and put in peoples assignments. When they pull up their TMS sheets, they'll know what they have to do and now that guy is responsible for getting those jobs done and buying them off when he's done and making any notations of any needed repairs.

FACILITY MANAGER: At the same time that you cut the fluff, you also add your experience. For instance, I know that these bearings, these limit switches, or what

ever need to be looked at regularly because they are in problem locations. The supplier won't know this because he doesn't maintain it, he doesn't call that out. So, ….

TNAP ELECTRICIAN A: : You look at all this stuff. We actually sat down and looked at all of this stuff. Some of it's good, some of it wasn't. So, we had to realistically look at it because from years of experience, you'll get straight answers. These guys have been doing this for years, some for decades. I've been at this business for 31 years now. If you ask me something, I can give you the history of the part. "Oh, that. Yeah, I've changed that part out several times. Usually lasts about a year and a half." Those are the things that you have the luxury of doing when you have this lead time. It's a benefit.

Typically, you'll that find suppliers don't know this because they don't maintain it. It's not their business. Their business is to build it, supply it to you, and sell you more. They don't maintain it. So when you ask them how long it will last, they'll usually call someone who maintains it and ask them because they don't know. They have to go to an expert, someone who maintains it. That's us. These guys actually have a better knowledge of the suppliers parts than the supplier does.

RESEARCHER: I think that, from the set up you have here, if there is an equipment failure, you notice it rather quickly.

TNAP ELECTRICIAN B: That panel over there tells us everything. We get alarms, bells & whistles, immediately.

TNAP ELECTRICIAN A: : On a lot of things, but not everything. But, if a line stops here, eventually another one behind it will also and then it will make its-self obvious.

RESEARCHER: What I was getting to is that there is a substantial investment in the facility – the walls, the floors, the ceiling, all the physical property that the equipment is mounted to. Do you have any kind of program where you go out and periodically inspect the facility its self as opposed to just the equipment?

FACILITY MANAGER: Yes, we have. There's where you decide on the facilities side of things. For example, the air houses. We have a service contract with a company that comes out twice a year for inspection on the unit, the HVAC. These guys typically do the PM on the doors.

There are some things that we don't do. An example of that would be the restrooms. We don't have anybody that goes around the restrooms other than the users. Obviously, those get PM-ed about every time we have a break. It's a facility that exists here but there is not someone who goes around to inspect them. The sanitation guy goes around and cleans it, that part of his routine would be to inform us that a handle fell off. Then, one of my guys would go out and fix it.

TNAP ELECTRICIAN A: : The columns, the ceilings and the floors; you don't have someone walking around unless you see something that is obvious.

FACILITY MANAGER: We don't have any inspections of those things. It has an expected life and you expect it to be there. Those are things that are structural. I shouldn't have to look at that for another 50 years. It's strictly the operating mechanisms that we inspect.

TNAP ELECTRICIAN A: : One other thing that was a break for us was having documentation, service manuals, and so forth in our hands. We went to electronic documentation viewer that allows us to view documents from several different software

programs with one viewer. It's not yet functioning perfectly, but we're getting there. We went to all of the vendors and told them the format that we wanted their documentation in. We wanted them to be similar, we wanted the chapters to be the same, we want safety information to always be in a certain chapter. So we gave them a template that told them how we wanted it to look, including pictures and diagrams, prints and so forth. All organized the way we wanted it. The template was in MS Word, but there are other ways to deliver documents. More and more vendors are going virtual documentation on CD-ROMs and such. There are a dozen companies out there making software such as Adobe. But we were able to view those.

So, as they come in, we're able to load those to our server and every smart display out there on the floor will have access to that information. Again, this software in the library allows us to organize it so that you can get to the information with only four or five clicks of the mouse. Most of the information has been loaded. Most of the vendors have been pretty helpful in giving us the information. In the past you'd get a hundred manuals, dump them in the corner of a building somewhere where no one had access to them other than one or two persons. Now, we've got access to it. Sometimes the information is good, sometimes it isn't helpful but as we develop more and more accurate information, we update it.

Something else that our guys are doing in house are creating what we call job aids. These are two page documents that tell you how to recover from a particular fault, how to perform a particular maintenance program or PM a piece of equipment, how to change a valve, adjust belts, lubrication, or what ever. It's a step by step, visual documentation of

how to accomplish those goals. A quick reminder. Those, too, will be on the document server.

There's a lot of software out there that we looked at that, if you had a break down of a fault on a particular piece of equipment, that fault could trigger five or six ideas of how to fix that fault. We don't have that yet, but those types of software exist. So there are a lot of other ideas that we saw that we could use in the future because they want us to standardize how everything looks across the company. To change that would be expensive.

FACILITY MANAGER: Adding to what Jeff (Peak) said, you have to picture what's in the body shop. We have two main suppliers for our body shop. Maco® supplied our tools and Deerborn® supplied our conveyor system. So, it wasn't much effort for our two major suppliers to conform to the format that was selected. Now, you can imagine if you go to the equipment at this end of the building, pull a manual out, turn to the same chapter, you'll find the same information for another piece of machinery.

Over there, paint and trim, they had many different suppliers. We only had two to deal with. If you look for the safety shut down procedures in our manual, the body shop, it's in chapter two. What ever piece of machinery you go to in this building, it should be chapter 2. You can see the simplicity of this, it sounds great. I don't know how difficult it is to get all of the vendors to comply with that.

FACILITY MANAGER: In the assembly shop, we have about 50 suppliers that we forced that on, also. They have the same format. We went to them and said, "Here's the format that you'll follow: chapter 2 will be you safety shut down procedures." We were pretty successful in getting that done. So, if Jim goes over and works in the

assembly shop at least he knows that if he pulls out a manual, he knows the start procedure is in chapter 4.

TNAP ELECTRICIAN B: At the old plant we had no standardization in the manuals. Different equipment would have manuals with different layouts, different chapters, different everything.

RESEARCHER: Having the vendor put everything in to a common package, everything in the right place, is something that we've been doing in the Air Force for a long time. Particularly with aircraft. When you have a failure in an aircraft, you have to be able to fix it fast, particularly if you're in the air. TOs are written that way, the dash-ones, and so on.

I think it would be in the vendors best interest to come up with some standard form of documentation. Something that they could use competitively.

TNAP ELECTRICIAN A: : A lot of them are doing that, but they're all going in different directions. There's no national standard, because they're serving hundreds of different consumers.

TNAP ELECTRICIAN B: Not only Chrysler, but also GM and others. As much as we're doing, other companies such as Ford are also saying, "Here is the format we want you to follow."

TNAP ELECTRICIAN A: : And it may cost them a lot of money to do it 20 different ways. If it's electronic, then it's simpler. They can cut and paste it to whatever the format should be.

Something else that's going on is using the web to go to manufacturers. You have access to websites out there where there is tons of information that you can pull up within

seconds. We don't have access to the internet (here on the shop floor) except in little tiny pools due to the expense of the network and getting on-line. But, Allen Bradley® has a web-page that Virtual Library will allow us to go to that page and call up any documentation for any of their components that we use and then print out what we need, then and there. Again, access to that stuff is important and is getting easier to get to.

FACILITY MANAGER: As we improve our own corporate intra-net, there's now becoming the point where our intra-net will pull that information, bringing it to us so that Jeff, from his computer, can actually go to the Chrysler internet and see that stuff because it's been brought in to our server.

TNAP ELECTRICIAN A: : Something else that Chrysler is starting to do is when they have problems on launches – well, I don't know how long they've been doing it – but when we had problems in this area, they passed that information to the next launch, saying "This component's been failing," or "This component's working great." So you're able to learn from others problems and mistakes. Common starters or motors or drives which are $160,000 each; if they have a problem at the Jefferson plant or Windsor plant, we can head that off ahead of time, a lot of times. So, we get a lot of inter-plant communications going that helps share the knowledge.

We've talked about having individual web-pages for each plant just for skilled training. "Hey, we've got a problem with this piece of equipment." They may have a similar problem up at Windsor. For example, we've got a new monorail system that Windsor has had for years. They're very familiar with it where our guys are just coming up to speed on it. So again, sharing knowledge is helpful for us. I don't think we're there

yet, but by establishing contacts ahead of time, we can always call one of the cribs up there and ask somebody.

FACILITY MANAGER: We try to do as much idea sharing as possible. When we got ready to build this plant, we said, "The body shop here is going to be very similar to the one at the Jefferson plant." It's the latest body shop that's been built. Similarly, the paint shop is going to be built like the latest paint shop. So we sent guys to those places to talk to those guys and find out from them what they did, what they liked, and what they wouldn't do again if they were going to start over. So, when we talked to our suppliers, we looked for those things. We could argue that Jefferson was having problems, so don't do that here. Let's come up with a different idea.

RESEARCHER: Have you noticed if that's paid off?

TNAP ELECTRICIAN A: : This has been one of the best launches in Chrysler history, wasn't it?

FACILITY MANAGER: Yeah,

TNAP ELECTRICIAN A: : As far as quality build time, the facilities went together faster and they came in under budget. Something else our guys were doing were evaluating training. Prior to the people on the floor getting training, they evaluated the content of the training and helped define what skilled trades guides he needs. We basically had broken it into three different areas: preventive maintenance, the build shop, and the training group. All three were looking at different portions of this launch, to evaluate it and put their input into it. And, they did some training also.

RESEARCHER: That's all I can think of at the moment

TNAP ELECTRICIAN A: : From our point of view, it was very nice to be asked to contribute. So often, I feel communication doesn't happen and to be able to have an impact on a plant that, you know, I'm going to be here another 15 years, and we're helping pave the way for other guys. So, it was good for us to be involved with it.

RESEARCHER: I appreciate you taking the time to share your experiences with me. It's helping me out, not only with the research project but also in the long run. I'll probably be in the facilities business for the rest of my life. Picking up on your experiences will help me in the long run.

09 May 2001 interview with Ted Roberts, Facility Manager for the Toledo North Assembly Plant (TNAP) and Toledo Assembly Plant (TAP

RESEARCHER: The thrust behind my research is to determine how you, as a major corporation, determine your facility maintenance and repair requirements and how you go about getting funding in order to do the things that you've found need to be done. In the USAF, it tends to be somewhat separated. We've got Congress at the very top saying, "We think you need this much money for facility M&R, so here you go." But on the bottom, we're saying, "We've got all these buildings that need to be fixed and it's going to cost this much." And the two don't quite mesh. The pot coming down is always much smaller than what we think we really need. That's one of the difficulties that we're trying to overcome as we're maturing, growing.

So, can you explain to me how your company identifies maintenance and repair, them being two separate things. Maintenance being the preventive and predictive type work we talked about earlier, repair being, "It's already broken, how do we go about fixing it?"

FACILITY MANAGER: Probably, I can give you two scenarios. We have an old facility over at Parkway that we've had to maintain over the years. On the Parkway side of the business, which I think is probably more applicable to what your looking at because you said that you've got existing buildings that your trying to justify building new. But in the meantime, you still have to maintain them.

What we do every year is, put together an up-and-coming year capital budget plan. The reason for that obviously is that we know that we're going to have to do some things

to the facility to maintain it. What we end up doing is submitting a number of different topics with dollar figures associated with those things to say, "OK, our roof now is 27 years old. We've spent X amount of dollars this past year in repairs." What we like to do is take pictures of these things. In a lot of cases over at the old facility, we've got some saw tooth roof areas and valley areas that we've got sumps that go into the down comers which go into the storm drains on the floor. Well, where that roof is it, it's eroded, corroded, or rotted – some of them are wooden roofs, some are metal decks. But in any event, there are places like that that happens and we end up getting leakage there and anywhere along the path to the scupper. What we'll do is, as we're building cars and as soon as you get a leak you've got a problem so we'll throw some visqueen up or anything to route the water away from the process. And we'll take pictures of that. That gives us some pictures that we can attach to our request. "Here's an example of some of the conditions that we have here, and we've spent this much money with our roofer this year doing emergency repairs, and our evaluation from them…." We'll get them to provide some write ups where they say their recommendations are to repair these sections or replace those sections of the roof or something.

You get that going for you and then you submit a capital plan says, "OK, here's some of the things." Roofs are real easy because it's a real obvious one. It's an item that's very visual, I'll call it. Another is the electrical distribution system. If you've been adding process equipment and your loads are such that you can take readings off the substations and can say, "Here's where we're at capacity wise. We've already added this many breakers to the system, we're at capacity on these four substations, if we needed to add any more we couldn't."

And each year our vehicle processes increase. As environmental laws increase and you have to do more things. Every year as our model change comes along, we have to add two more pieces of equipment. Something comes along. Now you've got to start vacuum testing this line or start emissions testing this system, or what ever it might be. We have to do that, so we have to add another piece of machinery that you have to plug in or power up from somewhere.

We do submit those kinds of thinks. "Here's our need for next year. We need to add two more substations or we need to repair or replace the roof in these areas. And here's why." With our support data, we can accompany that. Whether it's pictures or bills from the prior year. Here's why we came to this conclusion and here's a letter from our roofing contractor stating that it's no longer economical to repair the roof in this area, there are too many bad boards in this area so you need to replace the roof.

RESEARCHER: Do you calculate the impact that the facility problems have on your production?

FACILITY MANAGER: Yes. If we've incurred any downtime as a result of some of those things, we put that in there because that certainly …. If it impacts the quality. There's a cost associated with those things. So, if we know that this impacting quality because we are unable to put all of the welds into the car because we don't have the power to do that. So, that impacts our quality, which means we'll have to repair that at the end of the line, which means another process with a cost, and all that. So, we include all of that information with the capital plan.

That gets sent to our corporate headquarters, and we've got people up there that scrutinize it, because they're getting it from all plants. They want to see who is telling the

best story. Who has the most need. They have a budget to work with, too. This is almost no different than you are. Our share holders would be the equivalent of your Congressional Budget Committee that say's, "this is all that you guys get." Our share-holders are a part of what say's that our operating costs are only going to be this much, we can't afford any more. From that, it starts filtering down and somebody gets a pot of money. For plants, you get this much money for operating expense. We all get to share in that, so we a all have to go forward with our budgets and ask. If we get lucky, theirs not many people asking for money. But that's never the case, right?

RESEARCHER: Not where I come from.

FACILITY MANAGER: Everyone is asking for more than there is in the pot. So, you try to support it with as much information as you can. That's how we do it. That's the methodology that we use.

In this place, being brand new, this was a little different in saying, "What's it going to cost us to do what we want to do?"

I printed out a few things before you came to give you a feel of what we do and how we do it as it relates to a new facility. There were some exercises we went through such as we had looked at what are some of the things that we wanted to do on the outside. We're not doing all of those things on the outside, but – if we were going to – what would be the cost of doing it, if we have to add it to our capital plan.

Now, you don't see costs on that, because we didn't put that on this spreadsheet. There are some pieces of information that is sensitive. The union… I mean, this is a union shop. Some places in the military doesn't have that restriction if you will. This is a union shop and we try to work with them. They'd like us to retain everything. They don't want

you to go out and hire a contractor to do roof repairs. "Send me, I'll go." That's their druthers. And I can see their point of view. They're a business just like we are – to make money. The more members who are paying dues, the more money the union is making.

So, they have their focus or objectives. We have ours, which is to make the most money that we can make. So, we look at it and evaluate it from a business standpoint. We look at these things and say, "What are the "easies', the logical things that we don't want to spend our time doing with our tradesmen." Our tradesmen need to be focused on fixing the machinery that builds that car. That's what makes our money.

Now, we take a look at that and say, "Just to make the cars, and run the machinery to make the cars, it takes this many people." We try to shrink that down. For example, at the old plant building the same number of cars, we had 551 skilled tradesmen, here we only have 321. So, we've paired that down considerably from what that used to be.

We then take a look at the things that crop up through the year that need to be fixed, need to be maintained, need to have attention and something done to them but doesn't make sense to pull a guy off the floor to do that thing that only happens once every three weeks or eight weeks or whatever. So, we pulled that list together.

For instance, take substation maintenance. That happens only once every three years. Let's contract that service out to a service company. The door repairs, the roof repairs, the snow removal, the grass cutting. Stuff like that. What do you do with that equipment that you had to invest in for cutting grass in the summer? What do you do with that capital equipment you invest in for removing snow in the winter? What do you do with that equipment through the summer? And so on and so forth.

So, we look at it from a business standpoint and decide what do we do and how do we do it. That's how we developed what makes sense. There's no magic to that. It's strictly business. It's strictly business decisions that are made.

And then we take that and we roll that into our operating expense. We're establishing an operating expense (for this plant). At the old plant, we already had an idea of what we spent only it was a little skewed because at the old plant, we're dealing with a 100-year-old facility. Certainly, the money we spent on facility repair there, we won't spend anywhere near that over here. For obvious reasons.

The same thing with the condition of sub-stations, the condition of air houses, the condition of doors, the condition of the floors, the condition of the structural integrity of the shops. The difference between there and here is night and day. It's a multi-story factory, where this one is all on one level. The cost to do business there is certainly not what it is here. The efficiencies of things. Over there, trying to heat that place with the doors and the windows in the building and the walls being what they are, with the holes in the walls and the "this"s and the "that"s, air leaks and things over there where over here we're sealed up pretty tight.

So, we established budgets over there based on what's going on where as, here we're establishing new. And to establish the new, we used some of the … Most of our factories look somewhat like this. So we have other assembly plants out there that, other than the rate that we're paying for utilities, we know that to heat or air-condition or light so many SF, we know it takes this many BTUs or kilowatts or megawatts or whatever. From that, we use the local rates and determine how much it will cost to run the plant. We established things on those factors.

Then we start monitoring things and see where we can get better every year. We set targets each year to improve.

From an equipment point of view, on the plant floor, we do… We know that we've got a certain amount of machinery, we know that each day we develop what we call an MEB-6, manufacturing and expense budget. So, we say, "we know it's going to take this much manpower and we calendar-ize it throughout the year, by shift, by trade, X-amount of people. This is the budget that's over and above. The people who are here everyday, day in and day out, that's part of your normal budget. Over and above that you know that you've got to come in on holidays and weekends or when ever to do more service. It takes people to do that. We take that number and equate it out for a year. That's worth X-amount of people, X-amount of dollars, as people equate to dollars and cents. We work it right out so that it'll tell you how many workers you need: skilled tradesmen, sanitation, production. Saturday, Sunday, holiday's. What the price per hour for a total dollar.

RESEARCHER: Is this an estimate or pulled from historical costs?

FACILITY MANAGER: This is based on… In the case of an established plant, this would be based on existing data. For this factory, because it's new, we based it on some benchmarking of what the manufacturer recommends we do. For instance, they say to go in ten times a month to do something, that equates to one guy every Saturday to do that. We add it to the list. Same for other trades. For the process equipment, we then establish this based on, not only that but also manufacturers recommended activities.

We take all of that information and plop it on the chart and let it do the math and tell us how much we're going to spend on MEB-6 to maintain the shop. Over and above the manufacturing hours. From 6: 00 to 2: 30, we're building cars. The time we spend in

here with the tradesmen during the time that we're building cars, that's operating expense. That's part of the 321 skilled tradesmen. But, you don't calculate into that the overtime that would be expended to do stuff. That's what this (meb-6) does. So we establish a budget that accounts for the days that we're not building cars. And when we're not building cars, we know that we've got to get in and do certain things because that's the only time you can access certain pieces of equipment. So we have to establish a budget that identified for that period because we've already identified the fact that there's 321 guys we're paying for along with 2100 production workers that we're paying for and 212 material handling people, and so on and so forth. And those numbers are calculated into… As long as you build 600 or 800 cars a day, and you expend this many people, then you're within your budgetary numbers, which equates to building units and so much cost per car. But when you're not building cars, that's money over and above. That's were we establish those budgets. How much is it going to cost over and above our operating expense to maintain this place? And we start establishing that with these kinds of factors. In this case, it's strictly labor. Those are strictly labor costs.

On top of that, we do other things to pull out some costs. We'll take a spreadsheet that might say… We know that there are some spare parts that need to be replaced. It's part of a process that says we have to replace these every week, such as a filter. There are so many of them and we know how much they cost so we establish a cost for materials and stuff like that. Based on the preventative maintenance that the guys were talking about.

So, we go through this process to establish, again here it's a brand new place. We needed to establish some budgets that were over and above the operating expenditures so

we can decide what we're going to spend this year maintaining this place. And every year there after. This is the methodology that we use. We try to take as much information as we know, equate it to something… There's a lot of equipment out there, a lot of facility out there. So, it's not as simple as running your household, for example, but it's the same process. You still do the same thing. If you want to know what it's costing me, for example if your getting ready to retire, what are my expenditures going to be? Well, lets see. What has it been in the past? What are my costs and how are they going to change. We do the same thing, only it's a little more complex than that.

For example, let's take a look at your car. What will I likely have to do to it this year? Well, this year is the time I should get the engine rebuilt or change the brakes or what ever that may be and it's going to cost X-amount of dollars. That's a much smaller budget to work with than we're working with here but it's the same process. We do exactly the same thing, only on a larger scale.

RESEARCHER: It sounds like you've got a pretty good process for identifying or estimating what the costs are going to be to do these things and also what the maintenance requirements are going to be, considering it's a brand new plant and everything, there's always going to be growing pains. Do you have any type of rigorous method for going out and identifying actual work that is required to be done other than manufacturers recommendations. One of the guys mentioned monitoring bearing vibration…

FACILITY MANAGER: Yes. We do have a number of different monitoring systems in place. In our substations, for example, we do have what are called Power Logics®, through our SquareD™ system. So we're monitoring all of the power that's

being expended throughout the factory. As part of that, we use that data to take a look at areas of the plant where we're expending energy and changes that might take place in it. So, it gives us the opportunity determine why we're using more p0ower this month than last month, in this one area. Did somebody add more lights or more motors, or something. Or, do we have something out there that's failing and starting to draw more current. We have that information available to us. At the same time, like the maintenance guys said, we also have infrared scanning that we do and thermo-graphics and vibration analysis that we do. The guys are able then to say, "From what I can see, there's a hot spot developing over here. We need to get up and take a look at that. Is it a motor starting to burn out? Is it contacts that are starting to arc, is it wires that have become loosened? That's something that we do on a regular basis.

We also monitor all of the air houses. On the computer, we can take a look at the air houses and see what they're doing and decide from that… If we're starting to use more energy than we've normally been using, we take a look at some of the factors out there. What is the outside temperature? What is our unit operating at to get to the desired temperature? For example, we've set the thermostat to pump out 70-degree air. What kind of energy is it taking to get there? The METISIS software tells us that. That's the software that we have on all of the air houses that we're looking at. We do the same thing out in our energy center, which produces all of our hot & cold water for paint shop processes, all the compressed air for the factory. We have a system out there that's taken a look at all of those things, how much we're expending out in the plant and then comparing the data day-to-day out in the plant. What's it doing, how's it doing it, why it's doing it? What's different? What's changing? What's the condition of the equipment? If

it was drawing this much current yesterday, what's it drawing today and why? So, we have those things in place to help us understand or stay on top of some of those things.

RESEARCHER: Do you have any method for inspecting the plant? I know that since this is a new plant, you probably haven't gotten there yet, but… For instance, at the other Toledo plant, did you have a system set up where people went through on a periodic basis and analyzed the facility it's self to determine if the roof was getting ready to go or if it was good for another five years?

FACILITY MANAGER: We only do that on an as needed basis. We've never really set up a routine such as once a year walking the area and looking for corrosion or cracked beams, etc. We've not done that on a routine basis. From our experience of, through the year, I know I've gotten calls from this area or "I was putting in a machine over there…" Part of the process of putting equipment in is to inspect the area where you're putting the machinery in and making sure it's capable. That's part of the process of doing that. You also may find in the process of doing that, "I don't need anything here but I noticed over there, it looks like we're going to have to do something to that area."

Then we start turning in our capital plan for the year. Like I said, each year we turn in a capital plan for the up and coming year. That's when we take those things that we say, "You mentioned that you noticed a deficiency in that area when you were putting in machinery. Go out, take a look at it, analyze it, come back with a report for me, telling me that we're going to need to do something." That's when we'd do that inspection. That's kind of how we do those things. We're not as structured as perhaps the military when it comes to saying, "Here comes the team. You run out to that one, and you run out to that one, and you run out to that one." We don't do that.

However, we do some things that bring about some information. For example, we have a corporate team that goes around and does audits. Not building audits from a facilities needs point of view but more of a safety audit. We have an audit team that comes in, does a bay-by-bay walk through. The purpose of the bay-by-bay walk through is to look at items that we're either environmentally bound to, or OSHA bound to. So, they may do a walk through to see if we have any deficiencies as they relate to open wires or do we have back-flow preventors in place, or like that. Pretty much any deficiencies as they relate to safety. Emergency lights, exit signage in place. Those kinds of things. So those audits take place and as a result, there are some things that come to light. So, we gain from some of those types of activities.

RESEARCHER: Once you have all of the requirements identified, whether it be maintenance or other repairs, what steps are necessary to get the funds allocated to meet those needs?

FACILITY MANAGER: Same process. We do the same process… When we put our capital plan together for the following year, that's to get the pot of money. It gives sort of a rough draft of what you want that pot of money to do and as you do those activities that indicate that you have a need to repair something or replace something, what ever it is that you need to do. Then you actually go through the process of writing a project to really expend that money.

So, you write a project that says, "Here's what I'm really going to do and here's why." You have to do a justification, an in-depth justification. That's where you really start rolling in the facts: here's the number of cars we lost because of it, here's the impact in quality because of it. It could be a catastrophic event that may take place because of it.

Let's say that it's a roof that's about to collapse. If it collapses, it falls on 28 people, it renders the line inoperable, it'll be down for this length of time, preventing us from making so much product if that happens. We estimate that it could happen this year. Therefore, we need to take some of our capital plan money and spend it on this activity. We support that with the same pictures and documentation as we would have for the capital plan, only in much more detail.

And then that goes through our normal approval steps.

The engineers write the project. In the plant, we have teams to review the plans. I'm a member of one of them, I'll sign it to verify that it has everything in it from a facilities point of view.

It goes to our comptroller who signs it. It goes to our structural engineering group who looks at it to see if there is a manpower impact to what we're about to spend. For example, if we're adding a piece of machinery, will we have to add an operator to that piece of machinery? If so, there better be money in there to pay for a head. So, there's more to it than just that.

Safety looks at it. Using the machine example again, they look to see if it has all of the necessary safety features on it that we're bound to by law to have.

Our environmental department looks at it. Are there going to be emissions from what you're about to do that we'll have to get permitted for, all that stuff.

Then it goes up to corporate. They scrutinize it some more, may send it back with questions that are applicable to the groups up there that may take a look at it. They're looking at it from more of a global perspective, as it relates to… "Is this something that we want to do? You're about to put in a machine that we've decided throughout the

corporation not to use anymore. We've decided to this instead." We've got people who scrutinize that.

There are people up there that look at it from a warranty and service perspective on the car. "How does it impact that?" Numerous factors such as that.

Then it gets approved by one of our vice-presidents and sent on back to the plant. Then we have money and we go about spending it.

RESEARCHER: That sounds a lot like what the military does for large capital expenditures. The justification process is very tedious. And it has to go all the way up to Congress where line items are actually written into law and then authorized and allocated to the various installations where the work is to be done. It seems like it's somewhat the same in that particular case.

Do you know what Daimler-Chrysler's point of view is on capital investments? For instance, the decision to build this plant was made several years ago. What were the thoughts that went into the process as opposed to renovating the existing plant?

FACILITY MANAGER: Cost. Strictly a cost decision. Again, we knew we were going to build a new product. When we do that, we take a look at… "What's it going to cost us." If we're going to build a new product in an existing plant, that all takes time. For example, it takes a year to build a paint shop. You build it on site, unlike a body shop or assembly shop that you actually build the equipment off site then bring it in and assemble it. A paint shop, because it's sheet metal booths and sections and conveyors are integral to those booths, tanks, ovens, and all that. When you're building that, you say, "I've got a paint shop over here. If I want to build a new one, because I need to, because the process is all solvent based, out dated processes…" So you make the decision

at that point in time where, if I'm going to do that at the existing facility, I can't build cars for a length of time while I'm converting to the new. That's revenue. Every car rolling off that line equates to some dollar figure. You take that and say, "If I can't build for that amount of time, that represents this much loss in product. And, oh by the way, besides that much product that I'm loosing, I've got to tear down something then rebuild something. So the cost of that, if you're going to do it for the purpose of restoring, you have to take due-care. There's a cost associated with that. Tearing a building down with a bulldozer certainly is a lot cheaper than tearing it down with wrenches and hammers so that you take due-care so you can put something back into it. So, there's a cost incurred there and you say, "What's the delta of that expenditure?"

The other piece of it is the cost of restoring pieces of equipment, is it worthwhile? I can build or rebuild this roof, but what's it going to cost me to do that. If it's two-thirds the cost of a new or of this building, or in some cases more than. Some times, you can economize the costs. We built this building to $58 per square foot or less. If you can build it for $58 per square foot and $70 to $80 per square foot to renovate it, it becomes an easy decision. So, when we looked at doing this here, we had all those things in mind.

On top of all of that, we take a look at process that we're going to use to build the car. At the old plant, it is less square footage on multiple stories. In order to get material to those multiple floors, we have elevators. We've got to maintain those elevators. Those elevators are 100 years old, just like everything else is. You have equipment to get up and down those floors, conveyors that go up and down those floors. With going up and down floors, whether it's with pieces of machinery, elevators, conveyors, you name it, things break. There is more of a tendency for things to break rather than here on this plant floor,

everything's on one level. Nothing goes up or down big hills. When you go up and down big hills, we have a tendency where something will let go and slide down to the bottom of the hill and crash into three more cars. That costs you money, down time. We don't have that happening here.

So, there's costs that are incurred from the environment that you live within. So, you take a look at that and say, "What's that cost us every year to live?" In down time at the existing plant, a plant of that vintage, what's that think costing us every year? Just in equipment related or facility related things, we've already expended this much in both an annual budget of fixing that stuff and this much that's been incurred because of it.

So, you take a look at those factors, and that's what we did, and what made sense was to build a new plant. That makes more sense.

RESEARCHER: Who establishes the facilities maintenance program here?

FACILITY MANAGER: I do.

RESEARCHER: Do you have any policies that are dictated to you from your corporate office that tells you what you can or cannot do, or what standards you must maintain here?

FACILITY MANAGER: The only things that we have here, like I said, we have regulatory things that we have to do. For example, we have to annually inspect certain things, like back-flow prevention devices. Those have to be inspected annually. Any devices that put out emissions have to be inspected annually. Those policies are put into place and we have to perform those things. That's something that we have to do as part of either emissions EPA requirements that we have to adhere to. So, in order to adhere to

certain things, we have to perform certain functions as they relate to those items and make sure that we keep records of that.

There are safety things that we have to do. Inspecting emergency lights, for example. That's something we have to do annually. So, those are the policy type things that we have to make sure that we're doing. As long as we do those things, anything over and above that is at our discretion. If we decide that we need to add on to the building for what ever reason, there's nothing from corporate that say's you must add on 5000 square feet before you can add on one, or anything like that. It's strictly process driven. We decide what we need to do.

We do have engineering standards. We have what we call the Engineering Book of knowledge. It's what we do share through the corporation. Best practices. We have that on our corporate intranet. Any time we need to look at something, we can look that up in there. There are what we call "Manufacturing Instructions" that people have put together that say, "If you're going to do something, if you're going to build a building or put a floor down, our experience has told us that no floor shall be any less than eight-inches thick. It will be no less than fiber reinforced, it will be no less than what ever. The typical siding that we use is a two-inch sandwich siding with 22-ga corrugated steel sheeting. We will build no plant with less than a three-KIP load on any of the trusses. Our plants will be nothing less than 27-foot bottom cord (?) There are factors that we put into our Engineering Book of Knowledge that we'll try to… Anytime there are any improvements made, as a result of the things we do, we learn from it and we update it in the book of knowledge. Same thing for process equipment. We can go into a piece of breaky back and fill machinery and find that here are some of the best practices for doing

some of this stuff. And we've learned it. It's stuff that we've learned as we do these projects.

There are simple things in there. We've learned that when you put carpet down in offices, put it on to a substrate and use this kind of adhesive. Or put it on a substrate but don't use adhesive but instead do tack-strips. There are some thing's in there that are pretty simple but we've decided that… Even things that become a personal aggravation. "I had to go into this area, and I had to rebuild all the offices. And when I went in there, they had done this and it cost us 10X more than it would have if they hadn't done that. So, in our best practices, we say, "Any time you do this project, do it this way so that future reworks are cost efficient." So that's some of the best practices that we've put into our systems.

RESEARCHER: From our discussion earlier, I'd say that you put a lot of emphasis on your preventive or predictive maintenance. What's your perspective on that?

FACILITY MANAGER: We did that because the equipment is new. When the equipment is older, there are different schools of thought. It is difficult to quantify, qualify, and cost justify the need to do some preventative maintenance. At some point, where's the balance point? It is so hard, and we go through this every year… Someone will challenge you, "Why do you need to put oil on the hinges of that door? What cost justification is there for doing that?" That's pretty simplistic, but take that out on the plant floor and at what point do you take… You want to put oil on a conveyor and that's worthwhile. But why is it worthwhile to take out every pin and replace them every six months? There's something there that makes you say, unless I can really justify through, you know, there's proof out there that shows that if you don't do that every six months,

you're going to have failure after eight. But there is so much equipment out there has such longevity to it that for you to get good enough documentation on it to say that after 50,000 hours…. It'll take us 12-years to see that. Well, was it really because of that that you had the failure? Or was it because someone wrecked this in this section of the machine and that wreck jammed this and bent that bracket and that's why there was a failure. It had nothing to do with the fact that we didn't put oil on this or didn't change out the pins on that.

So, there is so much of that interaction between failure and just routine running processes, that's it's pretty hard. So, to say, "What's my perspective on it?" It's one of those fine lines that you have to take a look at from your experience and say, "What do you know definitely has an impact on the functionality of the equipment?" I know that I need to put a drop of oil on every link-pin. That's a given. If I do that, the odds are that it will run forever. But, how often do I need to go in there and replace that chain? If I'm doing my drop of oil, it might be 150 years. Somebody could argue then that, "Don't you remember when that chain broke last year? We should have replaced that chain just before that happened." Yeah, but why did that happen? Did it have anything to do with the fact that we jammed something down stream and the drive was strong enough to pull the chain apart? It had nothing to do with the chain being weak. It was an event that caused it.

So, you take a look at the things that you know are the right things to do, and you do those. From there, it's strictly experience. More than anything, it's that. Like the guys were saying out there, they come forward with recommendations. They know from their experiences what they've seen in failure in the past. They proposed a lot of things that

were the right thing to do. But even though they may have been the right thing to do, they brought it to me. I was the ultimate decision maker on a lot of the things that they did. There were some things that were done on a cost basis. Was it worth the Money?

For example, the tool watch program they have out there. Their first recommendation was to get a laser etcher to etch all of our tools. It was a million dollars per machine. Well, show me there is some justifiability for that. Are we going to save a million dollars in tool theft? Show me where it's justifiable for us to do that or is it just that it makes a real pretty label?

When it came down to it, it makes a pretty label. And we can do the same thing with this $5000 program that we ended up investing in. It accomplishes the same task.

So, that's kind of how we got where we are and the logic we used to get there.

RESEARCHER: How are employees taken into consideration with quality of the facilities that you have here. I realize that you are a union shop here, so there are probably some minimum standards that come from there. Are there any standards from your headquarters that dictates the size of rooms, type of carpet, anything like that?

FACILITY MANAGER: Yes. Offices, for example. We build offices based on pay grades. That's what dictates what you'll have in the way of a space. You'll notice that enclosed offices are few and far between. You see mostly open cubicles. The cubicles are for a lot of the workers from grade band… We have grade band that dictates… A 9 X 7 cube belongs to a certain grade band. A 9 X 9 cube belongs to another grade band. A 12 X 12 is another and a 12 X 12 enclosed office is another grade band. That dictates the office sizes.

The furnishings are a corporate standard furniture that is in fact dictated to us. You can not buy another table besides this one. This is the corporate standard table. This is the corporate standard file cabinet, binder bins. They are spec'ed by a department up in corporate offices that say, "If you're going to outfit an office, this is what you'll use. You'll get this many file cabinets, this many binder bins, etc." And, lower and lower grades get less and less.

Every office has a red wheeled chair and three sled-based chairs in blue. That's a corporate standard. That's dictated to us.

As far as from a facilities point of view, most of that is driven by code. The code say's that you'll have an egress point every 200 feet. You're going to have a bathroom for so many employees.

For employees, there where I'll say we do some things based on employee comfort that might be over and above. We take a look at how we do our business. Our corporate standard say's that you're going to take the bathroom standard, for example, where the building code say's you'll have X-amount… For every hundred people, you'll have a stool. Well, we double that. And then we take another look at how we do our business. For instance, we'll be shutting down the plant every day at nine-o'clock for a break everyday. Since we're doing that, everyone will go to the bathroom at that time. And the normal, "I'll go when I need to," sort of thing goes out the window. So, then we triple the code requirement so we know that we'll have enough bathrooms out there because we will be doing mass relief. Things such as that.

We do take a look at creature comforts. How often do you need to put drinking fountains in the halls? There's nothing that say's you need to put one every so often but

we take a look at our population clusters and make sure that we've got one in that area. The purpose of that is that we want the people to be as productive as possible on the job site. And if they do need to run off to get a drink or go to the bathroom, then it's close to the work station so they get back as quick as possible. Those are the kinds of things that dictate how you do what you do.

RESEARCHER: Do you ever defer facility maintenance? I know that you don't defer equipment maintenance because that's your bread-and butter , that's where your income comes from. But, let's say, the carpet is worn, not yet a tripping hazard, but definitely due for replacement. What determines when you do the replacement?

FACILITY MANAGER: And the furnishings themselves, the tables, the chairs… We have a chart, a standard depreciation chart. No different than your house. If you're renting properties, you can use a straight-line depreciation over 20 years for a home. We do the same thing for capital expenditures and appliances.

We know that things, whether they're process equipment or other… Robots, for example. Typically, they get depreciated over five years. Machinery, 15 years. Buildings, 30 years. Those things get depreciated for tax purposes over time. Using that as a basis, we use that as one of the factors. And certainly wear, that would be factored in. So, you take a look at whether it's been depreciated yet and what's cost me to maintain it.

You know, my car that I use in my business, I can depreciate it over three years. The government allows me to do that. But, also, I can get five years before I really need to start doing any major expenditure on it. So, I look at it from a cost point of view. Let's see, five years, I've already depreciated it so I'm not getting my tax benefit from it any more. It's starting to cost me so much per year to maintain it. Would I be better off

buying a new one? At what point in time? No different here, we do the same kind of business. We depreciate our equipment based on a chart that tells us what the accounting department is using for depreciation for our equipment and then how much is it costing to maintain it.

So, for example, using your carpet example, we know that office equipment has a life expectancy. So we take a look at that. Has it been premature? If it has, we have to take the cost of that asset and write it off that year for the rest of its depreciation value. There's a cost or penalty incurred with that. If it's already gone through it's expected life, then that becomes an easy decision. Now, if we've got someone coming in and repairing that every year, it may make good business sense to replace it.

RESEARCHER: Would there be any reason to defer doing the job? Even if you've already reached the end of your depreciation cycle and the facility is in need of what ever repair you're thinking of doing, would there be a reason to defer the maintenance?

FACILITY MANAGER: Yes. Again for the same reason that we talked about earlier. It depends on what kind of job it is. If it is carpet replacement, will we do that with our own people? No, it doesn't aid in building the car. We're using our in house maintenance people for that, we'd use contractors. If we had our druthers, we'd use contract labor to do it all. It's a union shop, we're bound by certain restrictions, employment levels.

Like I said. We hire an employee, that's 8 million bucks. We know that to be that because, by our contracts, once we hire you and we lay you off, we still pay you. We still pay you… We're bound to pay you. That's one of the things that UAW went after long

ago was life-time employment. The method of getting life-time employment is to make the employer pay for you for ever. So, whether you're laid off or not, we'll still pay you. Something. You get 95% of your base pay for a certain period of time. Then there's other methodologies, called "Job Banks" So there's other methodology that keeps you still making money. So, the company's still obligated to you.

So, there's an incentive for us to keep you employed doing something. If we'd have our druthers, we don't want to invest eight-million bucks. We'd just as soon go out and hire Joe-blo for a few hundred bucks, come in here, do something, then get back out. We're not paying him benefits, we're not paying anything. He comes in, does his job, and goes home. But the nature of our business is that there are some employees that we can keep gainfully employed non-stop, forever.

RESEARCHER: Is there any specific way that you tie you're requirements identification to your allocation. In other words, is there… I think this gets back to the justification that we were talking about earlier. You've gone out and determine that there is a requirement to do something. Is there something that ties that requirement to the allocation of the actual funds?

FACILITY MANAGER: We do have audits. Project audits. When you get a project approved, and you go out and do something, we have financial auditors that come out and audit the project to see if we did what we said we were going to do. Is that what you mean?

RESEARCHER: Let me give you an example from the military side of it. In the budget cycle that the government goes through, a suggested or recommended budget is provided by the Department of Defense saying, "This is what we think it's going to cost us

to do business next year." They get that from the various services, generating those costs themselves. The Air Force puts together a budget, we're going to spend this, this, and this. This is what we think it's going to cost.

Typically, facility maintenance is assumed to be 1% of plant value. If the plant is worth a million dollars, then we should spend ten thousand dollars on it each year, just to do the maintenance, the sustainment half of it. In addition, we believe that there will be unexpected problems that will have to be addressed with repairs. And that's an additional three-quarters of a percent of the plant value. So each year, we are programmed for 1.75% of the plant value of the properties held by the Air Force for facility maintenance and repair. That doesn't include the initial capital investment, that's a completely different program. I think I mentioned that earlier, that's the line item signed by Congress.

Unfortunately, that percentage of the value of the plant doesn't really tie well to actually going out and assessing the condition of the facility and determining what is really needed. There is nothing that really ties the two together. What we end up with is, "Here, this is how much you have to spend, based on the property that you have, and don't come bother us for more." But we need to do three times that to get us up to a decent level of living because we've got people sleeping in rooms that don't have floors. There's no connection between the two.

Some companies that I've talked to go out and perform a condition assessment of the facility that they are working in. A complete and thorough one. In addition to the manufacturers recommendations, they also look at things that are going to need repairing in the next year. They put that all in their budget, justify it, defend it. Then it goes to a corporate board that reviews it, provides the money that you need.

In that case, the two are tied together quite well. You have a very good justification for what you think you're going to spend, and … That's what I'm trying to get to.

FACILITY MANAGER: Yeah, we do. Like I said, the justification process exists where we do forecasting of expenditures. But don't get me wrong. We have the same…

The same process goes on from corporate headquarters that says, "Share holders are going to do… Our operating expenditures and our profit margins are going to be this much, therefore, we can only afford to let the plants use an operating budget of this much next year. Just from what they know they think the operating expenditures are going to be. You may have submitted a capital plan where you're going to spend 38 million dollars next year, but you may only get 22 million. Here are the things that everyone thought are meritorious and deserving of a chunk of money. You asked for 38, you got 22 because when the shareholders got together they asked, "What's the economy going to look like next year? We think we'll sell 200,000 fewer cars next year than last. Our profits are going to be this much instead of that much. And if that's the case, let's not go into spending more than we think we'll make next year. So let's cut everything back by this percentage." We're bound by that same rule, that business decision goes on day in and day out, not just for us or the Air Force. It's business.

Then we still go through that same process of justification that say's, "We surveyed the roof, we surveyed this, we surveyed that. Here's our recommendations." We have been know to spend more than our capital plan. But when we do that, it's because of the justification, that tie, that need, the cost and the justification of it. When

you do that, what happens is, it goes up north and they look at it and say, "OK, those two assembly plants… It's getting close to the end of the year. He's got five million in his budget, he's got eight million in his. Let's take a million from each because these guys came forward with something that is definitely going to cost us money. They've proven to us that if they incur that down time, we're not going to make that profit that we need this year." So, the overall manufacturing of this hub of this wheel is still spending the same amount of money. It got plucked from a couple of other places and got put into this pot. That's exactly how we do what we do.

RESEARCHER: That's pretty much the same way the Air Force does it, only they take it and give it to somewhere we don't see it.

FACILITY MANAGER: And certainly, as the year goes on. This past year, with the economy doing what it's doing right now, all of the plants got a percentage plucked from them. Even this plant that is brand new, got tasked by 20%. To say, " We had to do this. If we don't… We know that we're going to sell this many fewer cars this year. There's no point in ordering off the menu when you know that your wallet is only this big. The bills going to come at the end of the meal.

RESEARCHER: My last question: What kind of aspects of the facility environment that you have here that you take into consideration while your building the place. I think you've talked about that quite a bit. You use the standards that are provided by corporate headquarters, OSHA standards, environmental standards, stuff like that. In addition, I gathered from talking with you that you do take quite a bit of the economic into account. My read on this is that economics drive the decisions within this company.

FACILITY MANAGER: Quite a bit.

RESEARCHER: If you don't have the money, you can't spend it, obviously. Just a fact of life. Beyond that, is there anything that you'd like to add to that?

FACILITY MANAGER: No. But, to add to the fact of the economics, we do use the corporate specs and in cases of what we do and how we do it. At the same time, there are latitudes of what we do. If you notice, there is some glass here, but not a lot of glass. Part of the reason for that is sort of a two fold thing. We looked at where we could use the glass for creature comforts or for mental comfort but yet not so much glass that I've got to pay a fortune to keep it clean. So, it's sort of a balancing act.

Same thing with the grass. Where do we want to put black-top, and then spend that money to build black top. Where do we want grass, where should be just put stone, let the grass grow. Those things went into the thought process of what we did here and it's because of recurring costs. Where do we want to spend recurring costs, year in and year out? That certainly is a factor. We, my department, handles that.

Dana Corporation

Interview Date: 29 March 2001

Location: Dana Corporation, Headquarters campus, Toledo, Ohio

The following is a transcript of an interview with Dave Dennis, the facilities manager for the Headquarters campus of Dana Corporation.

RESEARCHER: One of the things that my advisor suggested was to have you describe your company, the plant size, production orientation, administrative orientation and so forth so I can get a feel for the climate of your company from a facilities point of view.

FACILITY MANAGER: Being a manufacturing company, we're segmented in to what we do in the way of manufacturing, what we do in the way of research and development, and what we do in our administrative offices. All of Dana's facilities are maintained and are similar as you walk through them. They are very high on housekeeping, the reason being that a clean, safe environment is a good place to work. We recognized the value of that several years ago.

We don't have dedicated people in our plants to do janitorial work; everyone is responsible for their own work area. The philosophy is that everyone is responsible for his or her own 25-feet. With that thought in mind, people take care of their own 25-feet. There is no body that knows better how to maintain a piece of equipment than the person who has operated it for the last five years. That's what he does everyday. He is the expert.

When it comes to our admin and engineering offices, like the facility that we're in now, the corporate office, it's all about image. We want to portray an image to our customers and to the communities that we are a top-notch org and we believe that the best way to do that is to present an environment like what you saw when you drove in. If you arrived in a month from now, the tulips would be blooming, the snow-mold would be gone, the grounds would be lush and green, and you would have seen that we spent a lot of time trying to create that image. We understand that the image that people have of us today is the reputation that we will have tomorrow. We always want that to be a positive image.

RESEARCHER: Within the facility acquisition and maintenance arena… I'm trying to get a feel for the climate in which you operate in…

Let me back up a bit. Can you tell me the size of your plant?

FACILITY MANAGER: This particular facility is the corporate campus. We're sitting on 178.8 Acres. There are five buildings of which we have responsibility for.

Two of those are guesthouses that are for the board of director and important guests that come to visit with us. Recently, a guest that stayed with us was Queen Nor of Jordan. She was in the area and we let her stay in one of our guesthouses with her entourage.

We have a maintenance building and we have two large administration buildings. This building is about 128,000SF, including the basement. We have another building about 100 yards north of here that is about 48,000 SF, which is also an administration building. The maintenance building is 28,000 SF and is where we store our lawn mowers and backhoes. Also that is where our maintenance crews do their logistics.

That's the size and scope of the plant right here.

RESEARCHER: When it comes to the acquisition and maintenance requirements of the facility, can you give me your companies point of view of that acquisition: Is it considered to be an investment, or a sunk cost?

FACILITY MANAGER: Many of the building…We actually have a division within our corporation that is in the building leasing and construction business. They do that for the general public, it's called Dana Commercial Credit. Inside Dana Commercial Credit is a group called Shannon Properties, they are property development people. So, they may build a business park for anybody. However, Dana is a very large customer of theirs. For instance, we can specify that they go to Longview, Texas, where we're opening a new 114,000 SF frame plant for GM. GM has a plant in Shreveport (Louisiana) or someplace near there. We build our plants near where our customers are. Gone are the days when we would have one plant with 8,000 people in it supplying everyone from one plant. Transportation costs to great. If our customer builds a plant in Mexico, then we will also build a plant in Mexico to supply them. If we build a plant in Texas, then it's because our customers are down there and they demand just in time delivery. You can't assure JIT delivery of a product from Redding, Pennsylvania to Texas with all of the distance between the two, due to uncertainties of the weather, etc.

A lot of the products that we make are heavy. Dana is primarily known as a metal basher, a chip cutter. We make heavy metal pieces: Frame rails for trucks & cars, axles, transmissions, and such like that. It's pretty expensive to ship them around the country, so we pretty much locate our facilities where our customers are.

RESEARCHER: For existing facilities, do you consider renovation or at the end of its lifetime would you just sell it off or tear it down?

FACILITY MANAGER: It's hard to determine the end of a buildings lifetime. If it's still viable and still serving the purpose that it needs to meet, then any renovation or re-tooling that we need to do, we will do in an old facility. We historically, I'm going back about five years, we owned a plant in Auburn, Indiana, that made clutches. We literally unbolted everything from the floor of that plant, shuffled it, and re-bolted it back to the floor in a more conducive flow pattern. We then went right back to making clutches in that facility. That was the most cost effective way to deal with it.

We had a good labor force there, a quality product. But as new equipment was purchased to replace worn equipment, it would be placed wherever it would fit if it didn't fit in the space where the old equipment was removed. We found ourselves buying tow-motors just to move parts from machine to machine rather than just handing it to the next operator.

There are times when our products do become obsolete and we do decommission a plant. We just decommissioned a plant in Redding PA. The product was no longer being purchased by our major customer. They had re-sourced it from somebody else and we lost the contract. There was nothing coming in that we could retool the plant for in the near future. So we scrapped that plant.

RESEARCHER: It sounds like you have some sort of cost-benefit analysis that goes into the process prior to actually beginning to change a facility.

FACILITY MANAGER: Each one of our business units, and Dana is divided into seven different strategic business units, are responsible for their own profit and loss.

They, on their own, make their own decisions. Corporate office guides them. We are the bank. If one of them needs money for re-tooling or an addition to their building, they come to us with a presentation of their proposal. They have to have done all of their homework, with analysis of the various scenarios. It has to be well thought out before it even comes to this level at the corporate office. At the corporate office, we don't have a team that goes out and does all of this. We're here to guide the people and be a resource for the people. If they run into a problem, they can call us here. If it's a facilities related problem, chances are I know someone else out there that has already run into a similar problem. I may not know the solution; however, I have enough recall to get those two together so they can work this thing out.

RESEARCHER: Do you have other issues that you take into consideration tax base or anything else that would affect your bottom line?

FACILITY MANAGER: We look at a lot of things. Because we're in business to make money for our share holders and return value, as we're looking into the economy of building a new building, me most definitely look into what economic incentives there are, in the way of land, infrastructure improvements, what forms of tax relief we may get in an area. A lot of times, economic development does come into play and I think that anyone who doesn't look into those isn't doing a good job for their company.

RESEARCHER: Do you have any documentation that illustrates how your company is organized?

FACILITY MANAGER: Yes. (See attached)

RESEARCHER: Can explain to me how your organization determines the maintenance requirements for your facilities?

FACILITY MANAGER: Sure. Due to the economic conditions that our industry is going through, we're in a cost containment mode. As I show you around the building, it is not the premium building that it could be. I have pages of notes of repairs and maintenance that are needed but right now we're only doing emergency repairs and visible detractors. If someone gouges a wall, we'll fix that right away. A lot of the minor things we're letting go right now. Life safety is in no way being compromised: If it's a life safety issue, we're spending money on it. But our sales are down; our profits are down because we're very closely tied to the automotive industry. We're under extreme pressure to reduce our costs by up to 15% by some of our customers, which is hard to do because we've always been a lean and mean company.

Generally, we're very proactive in our maintenance and repair. It has to do with maintaining the image that we portray here. One of the things is that, by forgoing the preventative maintenance that we normally run here, ultimately, we are going to have to spend that money and then play catch-up. I figure we can forego preventative maintenance for 9 to 12 months. Then we'll start having unscheduled down time and unpredicted failures. The way things have been done in the past, and what we like to do, is we have a routine about changing light bulbs, appearance of the building, maintenance of the pumps in the basement, how's the chiller running. We run on a very proactive, not so much a scheduled lifetime of a component, but what is the impact if something happens to that. Most of my systems in this building are backed up. If something happens to the primary, then I have a backup. I try to keep everything in better than tip-top condition.

RESEARCHER: When the decision was made to delay the maintenance, that was a conscious decision. Was the additional cost of having to play catch-up later considered as an issue to be addressed then?

FACILITY MANAGER: Absolutely. Tony, the vice president, the guy I spent the morning walking around and doing a walk about the building, is my supervisor, we sat down, I told him what the impact would be and he pretty much understands that we will have to play catch-up especially if we want to keep our image such that it is. Once we go over the hill, it's real hard to make up, play catch-up. You'll see that I've got some carpet that needs to be replaced that we're not replacing. It's just that right now we don't want to spend any money because we're asking all of our plants and manufacturing facilities to contain costs. And if we do things that are very visible right now, it won't send the right message.

We have done some pretty creative things around here. I've got a wonderful staff. Because we're not doing new projects, we can do a lot of the other things that we normally would farm out. We can do them in house right now.

For instance, I've got my guys building walls, something that we never would have considered doing in-house a year or two ago. It would have been easier to call a contractor and say "I work nights in this building, here's what I need done." We're recognizing that it will take my guys three times as long as a guy who builds walls everyday, but that's what we're doing to contain costs right now.

RESEARCHER: Can you explain to me the goals that your decision makers had in mind when setting up this method of determining maintenance requirements?

FACILITY MANAGER: When it comes to the particular building that we're in right now, we have very high standards. Our policy committees, the five guys who actually oversee the operation of the company, understand the value of image. Dana's a very traditional company, 97, 98 years of heritage. We are looking at our maintenance as projection of our image. We know that today's image is tomorrow's reputation. We want our reputation to be that we're always a fine company, not only are they always there when you call on them but that we maintain our things well, the people are educated, dress sharply, have good values. These are all part of the image that we're trying to project because we want that good reputation. It's more of an intrinsic value than anything else.

RESEARCHER: What other methods have your company tried other than that currently used for identifying the maintenance requirements of this facility?

FACILITY MANAGER: This building has been here for 30+ years. It's been this way forever. I have no info for before then. I know all of the people that ran this building before me, my predecessors. I talk with them whenever I run into something that I haven't seen before. Even though they are retired, they always respond enthusiastically. If I invite them to lunch, they always come by (Laughs) to share some experience on a similar failure or scenario that they had to deal with in the past. I really enjoy the fact that I still have these wonderful resources available. The facility manager that built this building thirty years ago is still available and if I need him, he'll come.

RESEARCHER: That's really good, because a lot times the people responsible for building any of our buildings have been gone for years.

FACILITY MANAGER: If it was up to me, when we start to develop a building – after site selection is done, all the government related stuff is done, and when they get

out and start breaking ground – if it was up to me, I'd put a facility manager in that building before they even start moving dirt. I think it's important that the person that's going to take ownership of that building is involved in the building process. Not as project manager, because we have project managers that know how to motivate the contractor and get things changed and stuff, but more as a liaison. Someone to see that the as-built prints are correct. Somebody who understands how the building goes together and works with the contractors and sees how it goes because as the building becomes mature and comes off the honeymoon, as it gets out of warranty so to speak, that person is going to need to know how to get things done. And by then, they will have been able to collect all of the manuals and resources and know who did what and who is easy to work with.

It's also a good time just from an MSDS point of view, to have somebody there and require that if something gets delivered to that site that all of the documentation comes with it because it's a lot easier to require stuff as the building is going up than after it's built to try to figure out where all this stuff is and then go out and get all the documentation for safety reasons.

RESEARCHER: Can you explain to me how your company differentiates between restoration, which is repair type work, and sustainment, which is maintenance type work?

FACILITY MANAGER: We look at it in a couple of different ways. We run a combination of both. We have variable assets, which are the tables and desks that we're setting at. We replace them unless they are antiques. We have several pieces of artwork and several antiques that are in the building. We try to keep the building the correct

temperature and humidity to protect all of our artwork and all of our furniture. But things do get used and they get worn so we repair them. We've got a couple of contractors that are very good, so we use them. We turn over enough stuff in this building and because of the level of the people in this building, if I get a new senior executive, he isn't going to want to use the previous persons chair or desk. He's going to want a different couch. So, basically, I'm going to have a two-year-old desk that I'll rotate out of this building, probably to another office here in the Toledo area or put it on a truck and ship it to someone who needs a desk, then buy a new one.

When it come to normal wear & tear, we routinely replace things. It's not uncommon for us to go through at least once a year and repaint the entire place. In fact, we paint every night, touch-up. Well, not right now, but normally we have a painter come in on second and third shift to touch-up. I would say that the room we're sitting in is ¾-inch smaller just due to the amount of paint on the wall. It was last painted in December (2000).

RESEARCHER: As a follow on, how do you see maintenance vs. repair? Which would take precedence in your companies view? What I'm saying is, and this is how we spoke about it earlier, before the economic down-turn that we're currently in, you were saying that you preferred to have a scheduled maintenance that was on going and you met your scheduled maintenance and that would reduce your amount of repair.

FACILITY MANAGER: Correct. For some things, it's tough to predict maintenance. I've got a 31-year-old boiler in the basement. I re-tube-ed it's sister last summer, I'm going to have to put new tubes in it this year. It's not one of those things that you have an option on. It's a major piece of equipment. A boiler the size of the one

we have down there will cost well over $100,000 to buy a new one. I can re-tube it for about $8,000. It's nothing that I can put off because of the building – it's a four-pipe system – I need that to be available as a primary in the winter or a backup in the summer.

How we prioritize those? We don't. They're all blended together. Very rarely do we make that kind of repair because we do preventive maintenance. We have regular filter changes and greasing intervals for all of our bearings.

We actually do, at least on all of our large equipment, we measure bearing temperatures and take oil samples on all of our machines to see if there's anything floating around in the oil that we need to be aware of, in the way of preventive maintenance, forecasting down-time, checking bearing temperatures. Being a manufacturer, we know that a bearing will heat up before it fails. So, those are the things that we look at.

We know that, in the boiler room, the bearing temperatures run at 147-degrees for a particular piece of equipment. If it's always 147-degrees, then everything is ok. But if one day it's 150, that tells me that there is a problem beginning to happen with that machine. So, we start looking at it more often. We see if we can theorize what might be going on with that machine. Is it out of balance? Is there something stuck to one of the vanes? What are we looking at? Is there too much pressure on the front-side of the machine? Is there something not relieving like it's supposed to, causing it to strain? And then, if it starts to rise a little more, we make a determination (of when we will do the work). When can we find a window? Get all of the parts in here that we foresee that we're going to need to put in here. Let's get all the tools in here, let's put them on the floor, let's lay them down because we're either going to do it 2nd and 3rd shift or weekends because our company is a global company and someone is in here 24-hours a day, seven

days a week. So, if I take this building offline for any reason, I have to make sure that my backup can cover the building. So if I take my primary chiller off during the weekend, will my backup keep the building comfortable for whoever is working in here?

We're working around executive management meetings, weather, other building conditions, or end of the month. If we're closing, I can't turn power off during closing even on weekends. It's a lot of scheduling. I guess that's what makes it exciting.

RESEARCHER: You already answered question seven…

FACILITY MANAGER: I've only got six here (laughs). How'd you do that?

RESEARCHER: This is one that my advisor brought up. He wanted to know specifically if you do any type of equipment monitoring. He through out a couple such as vibration analysis on motors, ultra-sonic vibration sensors…

FACILITY MANAGER: We do power circuits. My electrician goes through and …

He wants a thermal imaging camera but they're about $25,000 and we're working with other pieces of equipment that are much less expensive. We had a thermal imaging unit come in. About two years ago we had a power study where they went into all of our electric panels, motor panels, and light panels and thermal imaged, took pictures of the ones running a little warm, we fixed them. Also discovered a problem with the main switchgear to the building.

RESEARCHER: Good catch.

FACILITY MANAGER: Yeah. Using this thermal imaging device, we've since got a handheld device where we take pictures and he (the electrician– ed) records what each circuit are running. Two circuits in the same panel can run at different temperatures.

One may have lights on it while the other may have a copier with a heating element in it (the circuit servicing the copier – ed) so it may run a couple of degrees warmer. But, we have a bench mark of what all of those should be and depending on what's going on in his (the electricians – ed) life cycle, at least once a year he goes out and checks on them. Usually, it's just a loose connection. He puts a screwdriver on it, tightens it up a quarter turn, and the problem goes away.

But we are doing that in our electric panels, we're very proactive in our electric department. We are doing our chillers. Our big-ticket items we do have bearing temperatures, we have the age. On our smaller motors, our circulating pumps and stuff, we do not have instrumentation on those in the way of remote monitoring. If they fail, we always have one or two spares around here because of the number of circulating pumps in the system. Fortunately, they're all the same pilot diameter, all the same pump.

RESEARCHER: Can you describe the level of in house maintenance capability that you have and the role that they play?

FACILITY MANAGER: I have a general electrician on staff here in this building. He takes care of our preventative maintenance in all of our electrical panels, he takes care of all of our fixtures and fixture maintenance whether it's the motion sensors as you walk into a room or changing the ballasts we have in any of the lights we have throughout the building. He also takes care of all of our house lines, the low-voltage electric data lines and phone lines. He does all the day-to-day electrical job orders – new circuits etc. He takes care of our emergency lights and systems. He also does general maintenance within the building.

I have a journeyman plumber who is also a boiler man. He has a steam license so he can operate a high-pressure unit, even though we don't currently have one in this building. He keeps his license current in case I need to send him someplace else. He takes care of all of our HVAC in the way of and minor maintenance and filters. He does all of our plumbing issues whether it is one of the numerous dishwashers we have. We have a full cafeteria here that has a lot of water fixtures in it. He spends a lot of time on them, especially on the garbage disposals. He takes care of all of our sewer work and plugged toilets. He takes care of all the general plumbing stuff plus he does a lot of general maintenance. He does a lot of meeting set-ups and moving things around for us. We have 18 meeting rooms in this facility. Everyone has different requirements. Some people need different equipment, some people need chairs and tables set differently so the plumber, for the most part, is a real handy man.

We've got a woodworking shop and can make little things or repair things in the shop.

I've got two grounds keepers, on the outside. They both have ergonomic backgrounds. They are responsible for the physical property itself including the fences surrounding the property. We've got about 135 acres of grass and turf that they take care of, 30 of which is irrigated. We've got about 18 acres of woodlands on the property, plus a bunch of fencerows. I forget how many trees… I think they have about 3500 trees in their database, which are just the ones they maintain. They have fertilizer records on, trimming records on, disease records on. They go out to them at least twice a year and actually look at them and measure them at three foot off the ground with a caliper. How

big is the tree? How healthy is the tree? They check it for insects and diseases. That's what my maintenance guys do, on the outside

Other than that, I've got a couple of other people in the building. I've got a purchasing person that purchases all of our M&R items, operational items. Buys all of that stuff not just for me but also the rest of the building too. Office supplies and stuff like that. As to directly reporting to me, that's what I oversee. The kitchen and security don't have any thing to do with what we're talking about so we'll just skip over them.

RESEARCHER: We've talked about identifying your requirements in light of the level of maintenance you desire to keep. Now we're going to shift gears and talk about the funding allocation half of the equation. How does your organization determine the amount of funds to be allocated for maintenance requirements that are identified?

FACILITY MANAGER: We run off of historical costs. Since the majority of our maintenance is on a pro-active basis, we have … we're continually doing a portion of something. We have a pretty good idea of what the current costs are because we just did it two-months ago in another part of the building. We know how much it costs to get a room painted on second shift. We know how much it's going to cost to change a room, change the drapes or carpet. We do it often enough that we can use historical costs. If someone asks, "How much will it cost to redo this office?" looking at the level of the office, I have within about $100 I can tell, based on their tastes, what It's going to cost them.

But, when it comes to budgeting, we look at what we spent last year. We know we want the same results. We factor in inflation or any other items that we may know. For instance, this year we forecast huge increases in energy costs so we factored what we thought that would be in. We knew where we were making cost savings on some things

because of technology improvements and actually where the costs went down. Then we presented our budget. We've been fortunate here.

Question number two is coming us (laughs), which will lead me to the rest of the story.

RESEARCHER: How does your organization allocate these funds?

FACILITY MANAGER: We work off of a forecast. We currently run a 6-quarter system. It's adjusted monthly. By running a 6-quarter system and adjusting it monthly, there are absolutely no surprises.

How a six-quarter system works, is: I project six quarters ahead of what I think my expenses are going to be. So, when I get to the end of this fiscal year, I already have the next year forecasted. So, in the way of planning, we have an idea of where we think we're going to be a year in advance of where we are.

As things change, and there's always going to be fluctuations, if I see that I will need a huge capital improvement or something and I need $100,000 for a new boiler if I can't retube the existing one, then I can slot that in one of those spots, anywhere in the program, letting them know that I need that capital or they're going to freeze. That doesn't usually go over very well around here. I kid with the secretaries here "Buy them sweaters or a boiler, guy's." And that usually helps me out quite a bit.

But (seriously – ed) using that 6-quarter system – and everyone in the company uses this system – we have an idea of what all of our expenses are going to be. And we adjust it at the beginning of every month. Our numbers come out on the 5th business day of the month for the previous month showing how we fared on our forecasting. What do we know that's going to impact next month, or next quarter, or next year?

RESEARCHER: Does your company take into account the re-capitalization rate i.e. the length of time required to replace an existing building at the current rate of investment?

FACILITY MANAGER: Absolutely. Depending on the scope of the investment and its expected service life, we look at the expected payback and/or cost savings. For example, when this building was last renovated, one of the things they looked at was changing the light fixtures out. We went from the T-12 lights with magnetic ballast to the T-8 lights with electronic ballasts. We looked at the electrical consumption of the electronic vs. magnetic ballast and determined what was the payback. When you looked at all the fixtures that we had, and even thought electronic ballasts were three times more expensive than magnetic, there was a cost payback of less than two years.

Since then, the cost of electronic ballasts have come down and their not much more expensive than magnetic ballasts. We're making money now. There was such a drastic change in our power consumption that the power company sent someone out to check our meter.

RESEARCHER: How do your customers – and customers can be defined as management or someone off the street – how do they feel about the level of quality you maintain your building at?

FACILITY MANAGER: You know, you're right about customers. We have internal and external customers. The majority of the people we have in this facility are internal customers. We learned the internal/external thing when we started….

We've won the Malcomb-Baldridge award twice. Our Dana Commercial Credit won it several years ago and then just this past year, one of our manufacturing divisions

won the Malcomb-Baldridge. So, everybody in the company has been schooled in the philosophy of continuous improvement, quality improvement, quality assessment, so we're all aware of how that customer works.

The team that I work with is responsible for that "wow" effect that this facility has. When a person comes to this building for the first time and the first words out of their mouth isn't something along the lines of "This place is spectacular", then I want to know about it. It means it's missing something. I missed something in the morning, something's not right; because that's the effect I've been charged to create with my team. And we're very resourceful about creating that. Most of that is done through the outside, but when people walk into the building, they have a similar effect as you did when you met Mary Patton (the receptionist – ed). "This is someplace else." Which is the exact words we want people to say. Once that's done, then we're fine.

Those are my external customers. But they relate directly to my internal customers, which are the executives in this building. Now, if there's a problem with that external customer, he'll tell the internal customer and then I'll hear about it. I've never gotten a phone call in the four years I've been here, from one of my internal customers about that "wow" effect of something being wrong.

What I look at, and a lot of times when people call me, when it come to a maintenance issue, they start with "I hate to say anything about this…" I try to affirm to them "please don't be that way. If you see something that needs my attention, bring it to my attention." My staff and I have divided this building up and we rotate so don't see the same things every week, but we walk through this building every day. Usually before eight-o-clock, before everyone gets here, looking for things that need attention, something

that was damaged the day before. The house keeping staff has also been asked to do that and to leave notes on our desk of things that need to be done. We work with second and third shift and they leave us notes during the day.

Internal customers that are asking me to do things get immediate response and a lot of times we can solve the problem right away. The level of the people we have in this building and their expectations are such that, when they call us, it's at the last second that they remember they need something and we try to take care of it right away.

We often get recognized. Once a quarter, in this building we have a plant meeting, called a people meeting, where everybody, the HR department gets everyone together and "here's what's going on," "he had a birthday," and "here's an award for 15 years," and so forth. Usually one of the executives is there to give us a recap of what's going on in the company. There are 85,000 workers in this company. 158 just happen to be in this building. He communicates to us on a personal level, what's going on in the company. At everyone of those meetings, one of the members of my staff gets recognized by someone in the building who submits to the HR department a name for anyone you want to recognize for accolades, for going above and beyond the call of duty. One of my staff has always been recognized during that meeting for response time or a particularly nasty job. I have an excellent staff. But the people in the building are excellent customers and we work with them. A lot of times what we do is emergency response. It's an emergency to them but it's day-to-day operation for us. We fight fires in this building.

RESEARCHER: Have any comments been made concerning the environment, and I think you just answered that one.

FACILITY MANAGER: It actually all overlaps. And if it doesn't, if it's not all one package, then it gets segmented and then it's confusing.

RESEARCHER: Do you have any formal or informal methods for customer feedback?

FACILITY MANAGER: Everything here is informal. We have no formal thing where I would go sit down with a department head. A lot of times, someone will just stick their head in and say something like, "I don't know where you got that guy. I needed something and he got it for me in two-seconds."

All of the feedback that we get here is very informal. The only formal feedback that we would have would be the stuff that comes directly to me from my immediate superior. Most of the things he brings to me are all positive with only a few little projects for me to work on. That's our formal feedback program. Everything else, from the top down, is mostly informal.

RESEARCHER: What impact does the perception of the facility's condition by the employees working in that facility have on your allocation rate?

FACILITY MANAGER: Intrinsically, I think it does. I'm a firm believer that a clean, safe environment promotes productivity. I thought that way all my life, even before I came to Dana. I think that what we have to offer everybody in the way of amenities in this building, in the way of what we supply to them in the way of décor, atmosphere, and environment, that it's very important to their well being.

Since this is the headquarters of a global company, we actually have a little more open space in this building than a typical office building or any of our other facilities. If you look at a typical office building, it may have 100 to 125 square foot per person – A

six-by-eight foot cube plus common space and so forth, if you add that up it will probably come to 100 to 125 square feet. We're closer to 400 square foot per person. A lot of our real efficient plant people, people who are real efficient at plant design, come in here and comment on the amount of wasted space we have here. However, if we create "Dilbert-Ville" in here with density, then we do away with a lot of the image that we try to portray. As we tour the building, you'll see that we have wide aisles, a lot of floral arrangements, small clusters or pods that people are working in.

There are no mazes or dead ends. You can walk from one end to the other and see where you're walking. That has a lot to do with egress.

May background, in addition to my degree from Ohio State, I'm a fireman and I'm very involved in safety and life saving. So, I want to make sure that if we ever do have an issue, people can get out. So, we don't create mazes here. That's my personal goal, beyond the direction of the level of the upkeep of this building.

Coming to money, because of the economic conditions that our entire market is set in, I was asked last year to curtail my spending. I was able to knock 9% out of last year's budget. Minor things, so many things were works in progress that by the time you put the brakes on things, it takes three or four months for the momentum to stop, until you start to a return. But I was able to pull 9% out by the end of the year. They took what my ending figure was last year, my budget was approved, and then they said, "We need to save some money, can you help us any more?" My answer to that is "You bet we can, but you know the consequences are for dropping our preventive maintenance." Everybody bought in on it, with plans to get back to where we need to be when times get better. To date, I'm almost 23% below what I ended last year at. The two months that I have numbers for this

year, I'm down 23% from the same time last year. So we're doing extremely well but a lot of those things are paint that's not getting done, carpet that's not being replaced, office panels and cubicles that aren't being replaced.

I routinely replace chairs. People sit in a chair everyday. The people in the tax and accounting offices will spend eight to ten hours a day in that chair. The piston gets worn, and the upholstery …. It's not going to last forever. So I routinely buy new chairs: a dozen here and a dozen there. When someone calls, I give them one. Or, God forbid that someone break a chair while they're sitting in it. So I try to not wait until the chair is falling down or uncomfortable for them.

We're not doing that now. I'm waiting until there is actually a failure before replacing them now. I no longer carry an inventory in the basement; I'm not carrying on site a bunch of stuff. We're doing everything that we can to show that in addition to the corporate office waiving the flag and telling everyone out there that things are tight, don't spend money, be creative, be efficient; when the guys from the plant ask what we're doing, 23% is a pretty good number to show them. It's a good story. Short term, it's a great story.

9 May 2001 interview with Dave Dennis, Corporate Headquarters Facilities Manager

RESEARCHER: What came out of the [second committee] meeting was, the requirements identification that you do here is very good. The one question that came up…

Let me peel that back a little bit.

An area of weakness that I have in my research so far is in documenting the allocation methods the companies are using. Part of the reason for that is because its hard to get a grasp on it. Its hard to really explain how the money gets passed from one hand to another to take care of whatever requirements have been identified. Specifically with Dana, the thing that came up is the way that you go about doing your capital investment. How does a business manager or branch division chief come to Dana [Headquarters] and say, "We need to modify the line to do this that or the other thing. Here's why…" How do they defend the actions that they are saying they need to do?

FACILITY MANAGER: In the corporation… When it comes to the specifics that you're asking, we need to modify a line, we need to move this, we need to move that piece of equipment, a lot of those ideas are generated from the people on the shop floor. One of Dana's philosophies is that everybody is an expert within their 25 square feet. Me sitting in Toledo can't tell someone in Indianapolis what's best for them to do their job. I don't know their job. I don't know Indianapolis. I don't know that 25 square foot around that person. So, a lot of the idea, when it comes to plant layout and plant efficiency, come from the people working on the line who see the things.

I had a meeting with the Chairman this morning and he was relating the fact that you can get a lot of smart people who don't have any common or practical sense. They'll go out and buy this big machine and put it in the line and it won't work, and there'll be a guy on the line that says, "I could've told them that wouldn't work before they wasted their money on it." But nobody ever asked them.

Dana encourages everybody in the corporation to generate two ideas per person per month. If you take 85,000 people times two ideas per month, we get a tremendous amount of input on how we can maximize efficiencies in the plants, in production, in software development, in support services, in everything we do in the corporation. It's actually in our mission that we as employees will contribute to the success of the company. It isn't driven from the top down, it's usually someone at the bottom that says, "Here's why I think we need to move this line. If we do that, we can accommodate this other line, and here's why it's going to work." We have to think that that guy knows what he's talking about. So, we'll look into it a little more and find that, with a $180,000 capital investment, we can pay that back in five months or whatever it may be. It might be a two year payback, which is a long time in a big plant for $180,000. But there may be some ergonomic issues or other indirect paybacks that you can't measure. That's how those things are decided.

RESEARCHER: Can we use the recent plant announcement that you had for Longview, Texas [as an example]?

FACILITY MANAGER: Sure.

RESEARCHER: Correct me when I go astray because I'm not completely familiar with how your company actually does all this, but a need was identified….

FACILITY MANAGER: Yes.

RESEARCHER: … in Shreveport [Louisiana], for General Motors, I believe.

FACILITY MANAGER: That's exactly right.

RESEARCHER: Who actually developed the idea of placing a plant in Longview and defended it to the board of directors, saying, " We need to put a X-million-dollar plant in Longview because…" and then were able to defend and push that idea through.

FACILITY MANAGER: If you look at the business that we're in, a lot of the parts we make are heavy. We're metal bashers and chip cutters. The parts we make are very heavy so transportation costs are quite high. We try to, rather than have one 8,000,000 square foot facility and shipping everyplace, we try have small facilities with less than 100 people that are close to our customers. By "close to our customers," I mean within a couple hours drive so we can put stuff on a truck. With the business that we're doing with GM in Shreveport and the products that we're selling them for their future product lines that they're coming out, the decision was made probably within the Automotive Components Group that we needed to…

To be cost competitive, we couldn't afford to ship. So, part of our bid to them was at X-amount of dollars. In order to meet that, that meant the portion of that profit tied to shipping could only be so big. Then we start looking for an opportunity in a geographic area, maybe 100 or 200 miles around there… "Where can we find the infrastructure that we need? Where can we find the government support? Where can we find any local incentives? Where can we find a reliable labor pool? Where is there an education base that's already in place so we can use community colleges and technical colleges to assist

us in bringing these people up to speed with what we need? What facility [city] in this geographic area has all those things that we need for the business that we're in?" We ended up in Longview, which had the most components of the package that we needed: proximity to our customer, infrastructure already developed, resources available i.e. manpower, education… All those things came into play.

In our property development group, there was probably a chart set up that had maybe a dozen locations checked on it. As they identified which areas were strong and then ranked them, then we ended up with the winner.

RESEARCHER: It sounds, by the way you've described it, that your board of directors is predisposed to build a new plant if it's needed to meet a contractual obligation.

FACILITY MANAGER: In that type of decision, to build a new plant, was made several levels below the board of directors.

RESEARCHER: So, the decision to build the plant was quite a bit lower? I'm guessing, in the Automotive Group?

FACILITY MANAGER: It was in the Automotive Group. If we needed one in the off high-way group or where ever, that particular business unit would make their own decision on, "Yes, we do need the plant. Here's how we chose..." what ever little town we have.

RESEARCHER: Where do the capital funds come from?

FACILITY MANAGER: As the headquarters, we are the "Bank", so the various operating units will come to us, come to the headquarters and say, "Here's our project, here's our need, here's our payback, here's our benefit. We have a five-year or seven-year contract for this product line. Here's what the forecast is, based on what our customers

are telling us. Here's our forecast, based on what we believe the market trends are going to be."

There are times that our customer's forecasts aren't as reliable as our own. A good example of that would be the [Ford] Expedition. When the Expedition was released, Ford thought they were going to sell 40,000 units. So, in that first year of production, they only ordered 40,000 of the frame assemblies, axle assemblies, and stuff. We looked at that market and said, "That's a direct rival to the [Chevrolet] Suburban and that is going to be a …" Anyway, 120,000 units later – still in the first year – we were out of capacity. Suddenly, we were the bad guy's because they missed their forecast by a factor of five.

So, we have to do some of that factoring ourselves. But, those divisions come to the bank, the corporate office, come to the policy committee who are the five guys that are also responsible, including the Chairman of the Board who is also the CEO of the company, get together and make the decision that it's a worthwhile venture. Usually, by the time it gets to those guys, it's a done deal anyways. There's enough homework that's been done at the lower levels, it's more of a, "You need to do that."

RESEARCHER: Do they have a formal presentation, where they come up [to the headquarters] and …

FACILITY MANAGER: Yes. There is a formal presentation. Our policy committee meets once a month, usually the first Tuesday of the month for five or six hours on a formal basis. They see various project presentations from various groups that are going on. Maybe the IT [Information Technology] group is having a big project where they are trying to get everyone on a software program and we'll see all those

presentations. Very rarely do they say, "No." And, usually, if they shut somebody down at that level, it's because they know something else that's happening.

RESEARCHER: I've seen that myself, where I'm at.

FACILITY MANAGER: You can be as excited as you can and have all the support that makes in a no-brainer for a project, but if you're missing a crucial piece of information that's confidential because of something else… At the policy level, they can't tell you what it is because inside trader laws or all those other things, or something else that's happening. If they tell you, "No," at that point, you just have to say, "OK." Because, they know something that you don't at that point. Not that what you're presenting isn't valid, just that they know something else.

RESEARCHER: That's pretty much the thrust. It only took ten minutes, maybe, to discuss it, but… It's very interesting how you go about doing the allocation, particularly for a large investment like that.

One of the problems that we have within the Air Force is going up before the Air Staff, which is our corporate headquarters at the very top, and before The Congress and defending the projects that we need, to get enough justification to get the funds that we need. For various reason, Congress doesn't like to give us money. Because, well, from what I've studied, about half of all of their discretionary spending, as opposed to entitlements such as social security and stuff like that… Half of the discretionary spending goes to the military. So, if they can cut a little bit out of the military, that may allow them to build a new bridge back home. So, they're always chipping away at the DoD budget.

So, one of the things that I hope comes out of this study is a better way or perhaps a better angle to take when presenting these things so they can see the value of the investment.

FACILITY MANAGER: It's entirely possible that you could put together a committee of 12 people outside your industry that could pre-review things before they get submitted and get the folks at the other end to agree that they are going to screen them … Not a rubber stamp, mind you. But some people who have some business moxie, some people who really have some discipline, so that they will really review things in depth, and let them determine it before you go out and say, "I need $250,000 to fix a sewage treatment plant," or, "Yeah, I have to because…" If there was someone else from outside the organization who could pre-screen it, who had credibility with …

RESEARCHER: That would de-politicize it.

FACILITY MANAGER: It's just a thought.

RESEARCHER: It's a good one.

General Motors

Interview Date: 14 May 2001

Location: Plant Engineering Department, General Motors Moraine Assembly Plant, Moraine, Ohio

The following is a transcript of an interview with interview with Paul Dorsten, Plant Engineering Department Manager, and Dale Burnside, Industrial Engineer.

RESEARCHER: The thrust of this research is that I'm trying to determine how companies go about determining what their requirements are for facility maintenance. Not necessarily equipment maintenance, but facility maintenance. And then, how you go about getting the funds needed to perform that maintenance or repairs if you have repairs that need to be performed as well. And then, I'm looking to see if there is some tie between the way you identify it and allocate those funds and also if there is some tie between the quality of the facilities that you're in and the quality of the product that you produce.

So, to begin with, can one of you describe for me how you go about identifying your facility requirements?

PLANT INDUSTRIAL ENGINEER: Why don't you start by talking about what you did before World Wide Facility Group came into being.

FACILITY MANAGER: Let me explain where we are. The current condition is that, probably about a year or two ago, the corporation decided that there was a better way to manage facilities from the facility end of the business. That would be the building, the docks, the HVAC, those things. They felt that the plants job is to get the product out the door. Their natural focus would be on the equipment, get the head count out, do the operation, rearrangements for improvements, that sort of thing.

RESEARCHER: Was there a reason for making a change in their thought process?

FACILITY MANAGER: What I think that they figured out, and they probably did some looking at it, and they found out that we weren't really competitive at the cost we felt we were paying to maintain the buildings. I don't know how they did that, but it

came to their attention that, hey, we're not getting our bang for our buck on our money that we dedicate to our facilities. We were probably doing a lot of knee-jerk stuff, like with our roofs and stuff. We'd wait until there was water dripping in and then we'd address it because, ordinarily we're focused on keeping the place running…oops, we've got a leak, better go and fix it. We we're not really very proactive, we were really reactive.

And they said, "Hey, we can do a whole lot better than that." And they took and chartered the World Wide Facilities Group. It's a group out of the central office that is just that. They've got more people with construction expertise, more people with the building maintenance expertise, and they said, "We need you to go to all the different plants, not just assembly, but all the plants. Start looking at the focus on facilities because you're dedicated. You don't have to worry about the product; you just worry about the facilities." And so they started looking at how we can get better and they put together packages for better roofing. They put together packages for putting energy management systems and those kinds of things. That was their charter, they were to focus on facility maintenance and get better at it.

We're still in the transition, we're still growing. What we did, was we put a person down here who was going to manage the facilities and we kind of transferred some heads to them out of our heads. It was just a air-picked number to be hones with you. So, we're in a curve where we're trying to learn what does it take if all your going to do is have these people concentrate on building maintenance.

RESEARCHER: You said that this was started a year or two ago?

FACILITY MANAGER: A couple of years ago. It just got to our plant, I'm going to say, six to eight months ago, maybe a year ago.

PLANT INDUSTRIAL ENGINEER: Yeah, about a year ago we started and actually transferred the heads in the last eight months. It's kind of unique, because we're unionized. The skilled trades people still work for Moraine Assembly but we've transferred them to the supervision of the World Wide Facility Group.

RESEARCHER: How many people?

PLANT INDUSTRIAL ENGINEER: I think about 42 of the maintenance type people and around 100 janitorial types.

RESEARCHER: You have in house janitorial services, then?

FACILITY MANAGER: Yes, we do.

RESEARCHER: Can you describe the size, in addition to the numbers, the scope of the facility maintenance that you do in house vs. what you'd contract out?

FACILITY MANAGER: We contract… what you'd expect, we contract out. Our force is to the point where, if we need… We don't do any of our own roofing. Even the patching, we'll farm that out. Dock maintenance. If we get a dock lock that's not working right, generally we'll send a mill-right down there and they'll repair it. But if we're going to replace a dock, then we'll generally contract that out.

Dock doors. If it's a blown fuse or jammed, we'll fix that. If for some reason it's a damaged door, we'll probably call some one in to fix that for us.

HVAC. We'll maintain it to the point where we'll change the filters, we'll fine tune it, we'll change a valve here or there. But if it has a big leak in it, we'll have an outside firm come in and do it for us.

PLANT INDUSTRIAL ENGINEER: Oiling conveyors, we do. But if we need a new conveyor put in, we'd probably contract that out.

FACILITY MANAGER: It's pretty much where we get to the point that we want to maintain it. Anything out of the ordinary, we have people come in and help us.

PLANT INDUSTRIAL ENGINEER: There are still areas that we keep looking at. Right now, we maintain our mobile equipment, like our fork lifts. Some day that could change, that could go to the outside. But that would probably be a union-management discussion.

FACILITY MANAGER: That would be. Right now, our people do it and they are union.

RESEARCHER: Do you have a schedule built for maintaining the equipment. You mentioned the HVAC system, changing out filters.

FACILITY MANAGER: We're still relatively in the infant stages of that. We have a system called MAXIMA, which is a computerized tracking and documenting system. Obviously, our primary goal was getting all the equipment on the floor but we do have one hourly person dedicated to getting all the facility equipment into MAXIMA. And then, by reading manufacturer recommendations, by past experience, by history, we adjust the frequency of PM. We're getting better at that. That's relatively new, we've been at that for maybe a year or two.

RESEARCHER: That sounds like something that you're using for both your facilities and equipment.

FACILITY MANAGER: No doubt about it.

RESEARCHER: Is there a separation between the databases…

FACILITY MANAGER: Well, I shouldn't say that. The hierarchy is, if you were to go into the hierarchy to pull something up, first you'd go into Moraine Assembly, and then you might go to the paint shop. Then all the paint shop would be brought up. Then you'd look at the number one spray group or number two spray group. All the stuff that has to do with paint would be in one hierarchy. Then you'd have the trim shop where you'd have all the equipment and conveyors. So, yeah. Then you could go under a facility heading which would have the HVACs, the dock doors, we log all of our maintenance on our fork trucks and all that's logged into MAXIMUM. It's separated but… It's one giant database but it's broken down

PLANT INDUSTRIAL ENGINEER: One of the things that you may find interesting is… This is a labor model that we kind of use to describe our maintenance time. If you look at all of our maintenance hours that are available, as 100%, 80% of it is spent on maintenance, 20% is spent on things like administrative and problem solving, and documentation of things. Not actual hands-on fixing something. Then we break that up into saying, 70% of it is proactive and 30% is reactive. I'm speaking in terms of all of the equipment that's out here as well as the facility.

This is kind of the model that we see our facilities running at in terms of the relative percentage of what they do. We're trying to get them to do the proactive as opposed to the reactive. If you went out there and asked a supervisor, they'd probably tell you this is way too low because that's what's in their memory. But, doing it this way (proactive) is what prevents this (reactive). So, this is where we're trying to get to.

Along those lines, then, we go out there and ask, "What does it take to do this on equipment?" For instance, here's conveyors. We go through and describe every single

conveyor. We put in some information about it, what the recommended PM is, electrical, mechanical, tooling. Whatever type it is. And then we differentiate between if you can do it while its running or when it's down. And then, we have to factor in when that equipment is available. From that, we can actually derive a number of how many maintenance people we need at this facility.

So, it's a little more oriented towards the equipment, but there's no reason you couldn't apply it to the facilities.

FACILITY MANAGER: And it won't be long before we will. It's only a manner of time. We focused on the big money first.

PLANT INDUSTRIAL ENGINEER: As you can see, this is just general assembly (about an inch thick stack of paper). The body shop is…

FACILITY MANAGER: Are you close to publishing that? Are they close to saying what the number are?

PLANT INDUSTRIAL ENGINEER: I'm waiting for an answer.

RESEARCHER: I realize that you've only recently introduced this plan, but have you seen any benefits from it yet?

FACILITY MANAGER: MAXIMUM or this?

RESEARCHER: The new plan that GM introduced about two years ago, the centralized facility maintenance.

FACILITY MANAGER: Well, I don't know. We're still going through some growing pains so I'd say, no, we haven't recognized any efficiencies yet. Dale, what would you say?

PLANT INDUSTRIAL ENGINEER: No. We haven't reduced any people. And I can't say that we've seen any improvement in the services, at least not yet.

FACILITY MANAGER: Yeah, but I hope we do.

RESEARCHER: But as you said, it's still in it's infancy.

Does your company or people here make a difference between maintenance and repair. For instance, I think you were getting to this when you were pointing this out here. Is preventive or predictive maintenance preferred over repair? Or is there any steps taken to actually do the maintenance ahead of time?

FACILITY MANAGER: Proactively? Absolutely. Once again, we're getting into where MAXIMUS is helping us but we've got a whole crew in each of the areas that does predictions. Thermography, vibration analysis, ultra-sound. We use all three of those. More in some areas than others because it lends itself better to one area than another. And we're getting to the point where we're getting smarter with that, too. We're starting to develop routes where we regularly take the thermography camera to the body shop and check things. That's a relatively recent development. We're developing that kind of…

RESEARCHER: Could you expound on the vibration analysis and that type of… I'm going to call that predictive maintenance.

FACILITY MANAGER: Right now, we use pretty solidly three technologies. We use thermography, which is temperature sensing where you look for hot spots on your bus duct. Or a water leak in your kinkless cable for your welding robot. Or loose wires in a cabinet. They can see where a loose wire is because it generates a little more heat. We use that all over the place.

Vibration analysis, we're using that generally where we have rotational equipment. So, absolutely, it's the life blood of the paint shop where we have big fans where when they get out of balance, they start wearing the bearings out, which is a big repair job. Pumps. Pumps for pumping paint, for pumping phosphate material, all that stuff. Paints probably leading the way in vibration analysis, although we do some in the body shop and some in GA (General Assembly)

And, last, we're really just getting started, is the ultrasound where we look for, specifically, air leaks. But it also… When you have a short in a control panel, it sends out a sound that can be picked up by ultrasound. We're just getting into that.

RESEARCHER: I have to admit, that's a new one to me. I had not heard of the ultrasound before.

PLANT INDUSTRIAL ENGINEER: In addition to that, we do things like rotating of back-up drives so that we can have some chance to see if the back-up works first of all. We also do a lot of maintenance on our standard guns, our air drivers, and stuff like that. We rotate stuff in and out all the time. We only have about an hour and a half between shifts here. Most of our equipment has to "be PMed" (have preventive maintenance performed) when it's not running. So, we try and keep that line running. At one truck a minute, we just can't afford to loose too much time.

RESEARCHER: Do you operate on three shifts here?

PLANT INDUSTRIAL ENGINEER: Two shifts… Three crews, two shifts. It's actually a little confusing. We actually work about 120 hours a week. Six days a week, it's two shifts, each shift is ten hours. But there are three crews. One crew goes on

and off. I'd have to draw you up a diagram to show you how it works. But essentially, it's two ten-hour shifts with an hour-and-a-half between; six day's a week.

RESEARCHER: And that gives you enough down time to do the maintenance on your equipment?

PLANT INDUSTRIAL ENGINEER: Arguably, no. We struggle with that.

FACILITY MANAGER: We're stuck between a rock and a hard place. You have got only limited amount of time to repair your equipment, so you could up the manpower. But then you'd have that manpower fairly ineffective through the week because you don't need that much manpower to keep the place running as you would to compress what needs to be done after shut down here. So, we're continually fighting that balance battle, trying to find that happy medium. Some of us would say we don't have enough time. Others would say that we just need to get better at it.

RESEARCHER: Can you give me a little history of the Moraine Assembly plant? How long it's been here? Have there been any major renovations of the facility, that sort of thing?

FACILITY MANAGER: Well, we started out in 1970… Well, I wanted to go all the way back to Frigidair. We started out as Frigidair. We were one of the plants down here. Then in 1979, we shut down Frigidair, sold it to White Consolidated, and we converted this plant to make up a small pickup truck, much like the Luv truck at the time. That took us the better part of a year to get it converted over so that we were in business in the '81 model year.

The next change was when we went to the Sport Utility, called the 440.

PLANT INDUSTRIAL ENGINEER: I'd say it was around '85, '86. Somewhere around in there. In '92, we did a major revision.

FACILITY MANAGER: The model we just discontinued, the 330.

PLANT INDUSTRIAL ENGINEER: And then starting in January of this year, all of this facility, this GA, is new.

FACILITY MANAGER: All this part, let me get this (map) turned around the right way. We're right here and all this is brand new.

RESEARCHER: that's a significant addition. I'd say about a third of the what you already had.

FACILITY MANAGER: About three-quarters of a million square feet.

PLANT INDUSTRIAL ENGINEER: We used to have our trim shop here, chassis final ran the length. We got it in this are here…

RESEARCHER: Part of what I'm doing, I'm writing up a bit of history to introduce the company and how the actual plant I'm touring came to be. And any changes that have been done. This facility has been here for quite some time. It's interesting to us from a military perspective that this facility has been here for so long and you are still using it when other people, for example, NCR… Granted, they've had a rather large change in … They've gone from making things to providing services. Their facilities are 40, 50, 60 years old, just like ours are. They've torn down a bunch of their buildings, where we're trying to remove our old buildings and replace them with newer facilities that are less maintenance intense. To find out how somebody like yourself was to do that is interesting.

PLANT INDUSTRIAL ENGINEER: The old part is about 1960 was build. The part across the street is much older. In fact, it goes back to the Wright brothers.

FACILITY MANAGER: I want to say 50, this building was built in 1950.

PLANT INDUSTRIAL ENGINEER: I wasn't here, but it goes back to that era.

FACILITY MANAGER: That was Frigidair back then. This plant, in fact, as Frigidair, built washers, dryers, ranges, the skinny-minny where they had the dryer on top and the washer on the bottom.

RESEARCHER: You've given me a really good idea of how you identify your maintenance and repair requirements and such like that. Can you now explain to me how you go about getting the funds for doing the repairs or what ever is necessary? Or, for instance, when you added this facility on, this addition, what did you have to do to get that.

FACILITY MANAGER: I'm not sure your talking to either guy who can help you with that. Unfortunately, the way GM did it is, we have some historical data, this plant has always had a budget of X-amount for their 5000 account which is their repair. I don't know how way back when it was generated.

PLANT INDUSTRIAL ENGINEER: There's two portions of it. The labor portion of it we can pretty much predict. How many people we expect to be here. We base that on evaluation reports, competitive levels with other plants within GM. And I can pretty well predict that for the upcoming five years, here's about how many skilled trades we have and about how much they're going to be earning. Both straight time and overtime. So that develops one part of the budget.

The material part, I don't know how they do that.

FACILITY MANAGER: I don't either. It was established way back before my time. Each year they look at it and say, "That's about 2% too much," and cut it. I'm not sure John has a better feel for how it is… We kind of inherit a budget every year, that's how it is. Major projects, say we need to replace a big conveyor, we'll put together a project where we'll write up a business case. How long it's been. How many times it's broken down, what's it cost to repair it each time. And then we go forward and that justifies putting in a new conveyor.

But as far as a 5000 account budget, that gives us money to buy spare parts, outside services if we need them, that kind of stuff, I think was established and we've just maintained that.

It's not very scientific. I wish I had a better answer for you but I don't know of any.

RESEARCHER: Is there a particular way that GM allocates funds down to the Moraine Assembly plant? Do they give you a budget at the beginning of the year?

FACILITY MANAGER: With the exception when we build a business case, we… Other kinds of business cases are where after a new piece of equipment is in place and we've got a better way of doing it, we say we can save three heads. That generates so much savings. And then you put together a return on investment for them and if it makes the grade, they say, "Yep, you're right," and they send us $100,000 dollars to replace three people with.

PLANT INDUSTRIAL ENGINEER: Likewise, we can do a cost avoidance project. We can say that we can see that this conveyor is principally for a water test. If we see that the conveyor is beginning to deteriorate and we see a window of opportunity

coming up over a long holiday or something, we can say that we'd like to replace it and it will prevent us loosing so much production. We've sold projects like that.

FACILITY MANAGER: But that's the out of the ordinary, that's the big hitters.

RESEARCHER: So, when you made this addition here, that's kind of the process you went through, you put together a business case…

FACILITY MANAGER: Not us. See, that's where it gets a little hairy. The people who did the business case for that are all in our central office up north.

PLANT INDUSTRIAL ENGINEER: I was part of that, up north. It's part of the product development process. First of all, they decide they need a new product, here it was the new Trail Blazer. Once they justify that they have a customer out there for it, and how much volume it's going to be, then they look over their plans. It doesn't automatically come to this plant. They see where it makes the most sense for it to go. And then they develop a budget of what they're going to have to do. They do preliminary layouts, how much building are you going to have to add, conveyors, etc. And we do come up with a project, which is a special fund within GM. Completely outside of the plant operations. Once we reach full acceleration, all of the equipment is here, and installed, then turned over to the plant for us to maintain.

FACILITY MANAGER: A new project like this is all done up north. And then they have a group that benchmarks to make sure that we're on target, and all that good stuff.

RESEARCHER: That sounds a bit like what we have in the military called Military Construction.

Are you familiar with the concept of capitalization and re-capitalization?

FACILITY MANAGER: Somewhat.

RESEARCHER: This was a capitalization project, because it's a new structure and new investment. Do you know how GM, at least the management, looks at capitalization and re-capitalization?

FACILITY MANAGER: The best we get to is where we add an addition to something and it's over 50% of the price, then we might re-capitalize it. You're probably talking to the wrong two guys here.

PLANT INDUSTRIAL ENGINEER: The only thing we know is we don't have floor space,

RESEARCHER: The last focus that I have for this interview is basically your customers. I view your customers not as the people who are buying your truck but the people who are working in the facilities you are providing, people like myself, a visitor, who comes through the facility. Do you have any way of gauging the quality of the facility you're providing to this customer? Do they have a way of telling you it's great or not good?

FACILITY MANAGER: We have pretty much daily feedback.

PLANT INDUSTRIAL ENGINEER: The employees themselves give us a lot of feedback. We have weekly team meetings. There's all kinds of ways they can feedback information. All you have to do is let a restroom go for one day and I guarantee you're going to hear it.

FACILITY MANAGER: They have a lot of recourses. They can talk to their supervisor. If that doesn't get them satisfaction, then they can call their committee man

and then it gets elevated. But there's pretty much immediate feedback on when we're not doing…

You're talking human comfort type things. You're talking facility now. If the air conditioning goes down, we'll hear about it immediately. If it's too cold in the winter time, we'll hear about it immediately.

Something a little more subtle than that is the housekeeping. We take weekly housekeeping tours looking at safety and housekeeping. That generally provides feedback to the people doing the housekeeping, too. There are some informal and some a little more structured ways of doing it.

RESEARCHER: Has the condition of the facility The impact of the condition of the facility on the employees be taken into consideration on the same level of maintenance that you are providing? Or is it all inside of your contract with the UAW?

FACILITY MANAGER: I.U.E. first of all. We're the electrical.

PLANT INDUSTRIAL ENGINEER: We're the only non-U.A.W. assembly plant

RESEARCHER: I'm sorry, I was making an assumption, and I apologize.

PLANT INDUSTRIAL ENGINEER: That's alright, few people know that.

FACILITY MANAGER: I'm not sure how to answer that. I guess we fully appreciate that it works two ways. If we provide a clean work place for these people they'll tend to want to keep it cleaner, produce higher quality, etc, etc. so yeah we take that into consideration, as far as trying to maintain a clean, safe, environment.

Mr. Burnside: We did two things on this last expansion, one is recognize that the people were always unhappy in the summer time because it's very hot and humid so we air conditioned the plant for the first time until this last year it never was.

Mr. Dorsten: Yeah, it would get into the hundred's at times.

Major Sharp: On the floor?

Mr. Burnside: Yes, many times.??

The second thing is we took some major steps to improve ergonomics with the relationship to the work force ?????????? and the skillet system down in ?????????? a lot of money we invested for no obvious payback but it makes it much better for the employees so that they are less likely to get repetitive motion type problems or extensions and things like this. From that stand point I think we're certain to recognize just how valuable our people are. They're getting more educated to in understand to that they have a right to demand a safe work place. So, we are trying to respond to that. Which is the right thing to do.

Mr. Dorsten: Did that get at kind of what you were talking about?

RESEARCHER: Yes, exactly so. Well, I've kind of gone through all the questions that I have pre-prepared is there anything else that you can think of that stands out in your mind as being important that I haven't brought up?

Mr. Dorsten: Well, I can't emphasize enough how important the Maxima and the predictive technologies are going to be for us. We are looking at that to really help us because you found real quickly where a pinch point is when you run an operation like we do where you run a 100-120 hour of production we have a very small window to "PM"

stuff so we've got to get better on the other end of it with planned maintenance and predictive maintained to where we anticipate where we'll have a problem and fix it before it breaks where we track a lot of machine history so if we thought it should last a month and it turns out that over the last six months it broke every three weeks well then we adjust our "PM" program so we're doing a lot more of that. And Susanne is helping us she's kind of our capacity assurance coordinator. So she is looking into that the people that do the Maxima work for her. So, I can't emphasize enough us getting into the predictive end of the business, the proactive end of the business

Mr. Burnside: I guess the end that I see is the economize wherever you can. If you have a facility and it has a power door on the outside it doesn't make sense to have twenty-five different kinds spread all over the country where you can go with the same one and the type of maintenance that takes with the one should be the same for the others it takes a lot of the guess work out of it. Obviously in your business you've got ((((to look and experience climate))))?????? And everything else but that's what we're finding that we have one kind of controller out here or one kind of drive….makes a difference.

Mr. Dorsten: We can leverage our resources a whole lot better.

Mr. Burnside: Yeah, now we can call up other plants and say 'How do you do this?' If they have the same kind of equipment and the same kind of facilities it's much easier to compare our answers.

Major Sharp: That's something that we've been trying to do in the military as well, unfortunately contracting law says we're not allowed to specify by name exactly what we want, 'it has to be a square D panel or equivalent'…yeah if it's Allen Bradley and it meets the requirements then…

Mr. Dorsten: Purchasing, purchasing, purchasing, I'll tell you what….we won't even share with you the kinds of things that we go through.

(Everyone joking and laughing)

Mr. Dorsten: But trust me when I say it isn't easy, 'Hey everything is square D', I mean….

(More laughing from all)

Major Sharp: Ok, well thank you for taking the time to talk with me…I appreciate it.

FACILITY MANAGER: Well, sorry it took so long to make it happen

Major Sharp: Hey, it's ok I understand you guys are busy

FACILITY MANAGER: If you have any other questions don't hesitate to call me Susanne is going to take you up and show…he'd like to see, I presume he'd like to see some printouts and walking through the Maxima.

Major Sharp: Yeah, they were telling me about the Maxima…now I'm going to turn this off.

End of Interview

Mead Corporation

Interview Date: 15 March 2001

Location: Facility maintenance office, Mead Corporate Headquarters Tower, Dayton, Ohio

The following is a transcript of an interview with Tim Hatton, Contract Facility Engineer (Jones, Lang, & LaSalle), and Brian Francis, Contract Facility Maintenance Foreman (Jones, Lang, & LaSalle)

RESEARCHER: Do you have any documentation that illustrates how your company is organized and how the facility maintenance section fits into that organizational structure that I may take with me?

FACILITY MANAGER: We're really going through a lot of changes right now, with the company, with just about everything we're doing. We've brought over now, we're Pressman, Jones, Lang, LaSalle. We are a contractor in this building who takes care of the property. We are presently going through quite a bit of different things as far as purchasing as a merger of several different companies. So, we're in a process of change.

Another thing that has happened to us is that we're almost out by ourselves. We're like an island, with a lot of stuff in Columbus [Ohio], a lot of stuff in Cincinnati [Ohio], a lot of stuff in Chicago, so they have groups that work together. But we are kind of all by ourselves, fending for ourselves right now, which isn't a good thing, but until we get some other properties in Dayton, we can't really benefit a whole lot like such a large group.

It's a little bit different with purchasing, as we can lump together in a nationwide buying power, where we get a better price. As far as me calling on someone else, a lead

engineer or someone else to call on, I do not have anyone to call on right now. We used to have a regional chief but not any more. What happens in this building, we take care of ourselves.

As far as an organized list, I really don't have anything to give you.

RESEARCHER: Can you explain to me how your organization determines the maintenance requirements for your facilities?

FACILITY MANAGER: A lot of that is a once-a-year audit. We have a set of goals that we try to attain. Also, a lot of it is safety issues and basically it tells us about the equipment. A lot of it is code, and has different categories broken down there and we base our maintenance requirement off of that.

MR. FRANCIS: A lot of it is what each individual pieces of equipment, what the manufacturers recommends, as far as actual preventive maintenance and then we set up our schedules accordingly, to the manufacturers recommendations.

RESEARCHER: Just from the quick glance that I made of it [schedules] it looks like you've outlined each of the systems in your facility and then come up with an annual inspection, go through and look at each of the critical areas of the systems and sub-systems

FACILITY MANAGER: Each one is broken down and graded. There are different levels that are pass/fail depending on what you're trying to achieve.

RESEARCHER: Can you explain to me what goals your company decision makers had in mind when setting up this method of determining maintenance

requirements? Perhaps I need to explain a little bit so you'll understand where I'm coming from. In the USAF, there are two methods that go along identifying requirements. Like yourself, we go out and survey the facilities but on a higher level, a corporate level, the funding is more or less fenced by the value of the plant.

FACILITY MANAGER: Our budget comes through Mead. How they come up with the exact figures, I set down in September and say all of the stuff that we need to do and the money for major improvements. It's not really based on the value of the building, more based on the needs and requirements that I believe the next year, I try to estimate the break-downs, repairs, what ever, and I'll go through the general manager. Then they go through and pick out what they want. "No you can't do that this year, it'll have to be done the next year", or "yes you can". Our budget is set like that, within this facility. As an overall organization, I think it's done pretty much on a property-to-property basis, because we aren't the owners of the building. The owners are going to tell us what they want to spend, what they want repaired, what they want upgraded. Basically it's the owners telling us what they want to spend. We'll take that money and apportion it to what we think the priorities are.

RESEARCHER: What other methods has your company tried prior to implementing this method for determine the maintenance requirements for your facilities?

FACILITY MANAGER: A lot of companies work off of a break down method. It's not really a good way of doing it, it's the "Squeaky wheel gets the grease". I don't believe we've ever operated that way, but a lot of facilities are.

FACILITY FOREMAN: As long as I've been here, even with the company changes, we've had an audit, a yearly audit, where someone comes through and, say, want to see all of the records, walk through all the rooms, all the floors and look at things that way. I don't think I can say that we've ever had something different.

FACILITY MANAGER: Our Audits have changed, but we've always had some kind of program where we'd come through and look. Before, it was pretty much someone would come through and …. The looks of the rooms had a lot to do with it, it better be nice and clean, painted. As far as the mechanical equipment, they didn't even check that. Now, I've seen a huge improvement where now they come and look at logs now, more energy savings stuff, like that. So our audit has changed, the method has changed.

RESEARCHER: The person doing the audit, are they familiar with facility requirements?

FACILITY MANAGER: A good point. It used to be that we'd have a house keeping manager or someone like that come in and they would not even know what they were looking at. Not know what the equipment was. That was recently changed. When we had a regional chief, he would come through and do the audit. So, he did know what the equipment was and what it should be doing.

FACILITY FOREMAN: We had a housekeeping supervisor come in here. He walked around in here, didn't know what any of the equipment was for. The only thing he got us on was that he said (pointing at the ceiling), "All of those pipes up there are dusty. Clean them."

FACILITY MANAGER: He just knew what he knew which was house keeping. So…. Things have changed a lot. Some for the better, some worse. But we've always had

some sort of an audit system in place but the current audit is a lot different than it used to be.

RESEARCHER: Can you explain to me how your company differentiates between restoration (i.e., repair) and sustainment (i.e., maintenance) requirements?

FACILITY MANAGER: The restoration work is a lot of what Mead requests. When we had the building cleaned and sealed from the outside. It was a huge project. It might not sound like much but when you're dropping scaffolding over the sides and power washing and sealing the building…. It was something Mead actually requested that we do so that was put into the budget, $250K, done by an outside contractor. All of the construction work and upgrade work in the lobby or someplace like that is requested by Mead.

Now, the maintenance requirements, that's something that myself and Brian, we'll decide what we need to do, and pretty much come up with what schedules, what piece of equipment we're going to tear down over the winter, cooling equipment, stuff like that. That's kind of up to us – Jones, Lang, LaSalle – Mead looks to us to tell them what maintenance is needed. They come and decide what construction work and what upgrades are needed, face lifts to the building, stuff like that.

RESEARCHER: When you're doing your accounting for type of work, do you differentiate between maintenance and repair?

FACILITY MANAGER: In the budget?

RESEARCHER: Either in the budget or just in the way you track the work being done.

FACILITY FOREMAN: If it's scheduled maintenance, it's preventive maintenance that we do, that is listed as scheduled. If it's a break down, it's listed as an unscheduled.

RESEARCHER: You do differentiate by whether it was preventative vs. more of an emergency.

FACILITY FOREMAN: Actually, we track three things. Unscheduled maintenance, which would be a break down of anything, we track our scheduled maintenance such as preventive maintenance programs. Then we have what we call tenant requests which can range from changing out light bulbs to moving furniture or hanging pictures.

RESEARCHER: What level of in-house maintenance capability does your organization have and what role do they play?

FACILITY MANAGER: We like to take pride in what we do in house. We do a lot of our maintenance in house. Until recently, we took care of all of our chillers ourselves. Now we have an outside contractor but we take care of all of our joy fans, it's all done in house. We pay for the crews, the labor charge just from working for us for a month or two. It's a huge cost savings to the company because we can do so much of this in house. There is some stuff that we do have contractors on: Large electrical work or high voltage electrical we do not get into. We have a contractor that does that. But we do a lot of stuff in-house. Whatever we can handle, is what we try to do.

FACILITY FOREMAN: There's not much we can't handle around here.

FACILITY MANAGER: There's some stuff that, for liability reasons, we do not do. We don't do elevators; another we do not touch is the window washing. Just for liability reasons. If anything were to happen, it's too great of a danger for liability and lawsuits. Everything else is pretty much fair game.

RESEARCHER: How does your organization determine the amount of funds to be allocated for the maintenance requirements identified?

FACILITY MANAGER: I don't know if they have an n exact percentage. A lot of this is probably over my head but I know what they like to see. They like to see at least a 5-year payback on any major project like if we wanted to replace a chiller; they want to see a 5-year payback. If it were not going to do that, they would be very hesitant to ok a large project like that.

As far as preventive, I go through and try to estimate what we're going to need, give it to the owner, which is Mead, and they have to approve or disapprove any project for the following year. Now, I don't know…

A lot of their budget is probably based on how pulp sales are doing or how the paper business is. They kind of put a crimp on us this first quarter because they didn't do to well. So, they won't do anything like a major improvement, like a hundred thousand dollar roof or something like that. They won't stop me from buying a $1,000 motor, something real small. But for major stuff, they will put a freeze on it. They probably won't do real well during the second quarter, so I've got a feeling that there won't be a lot of funds and they won't want us to do anything like a major project.

RESEARCHER: Do they have a monetary cap where you are required to talk to them for large amounts?

FACILITY MANAGER: Basically, our limit is under $10,000, give or take a little bit. (Looking at FRANCIS) What's your spending limit? $1,000?

FACILITY FOREMAN: $2,500. Anything over $2,500 I need your approval. What's yours?

FACILITY MANAGER: It was $3,000 but they just recently raised it to $5,000. Then it goes to our general manager. Anything over $10,000 and he has to go to Mead.

FACILITY FOREMAN: But how they do their calculations…. They have four floors of CPAs or something. I don't know, maybe they roll dice or something. (laughs)

FACILITY MANAGER: It started out where you had a thousand, I had two thousand or something and we were just running to them for everything. So, they said, this isn't working, we trust you to do what ever is needed. I make a light bulb order, that's a thousand dollars, so they said they didn't need to approve this. The limit was just too small so they raised it.

RESEARCHER: How does your organization allocate funds?

FACILITY MANAGER: Basically, it's our budget. That's how we … We update it month to month on which projects we're going to implement that month and that's how we get the money or allows us to spend the money. The overall budget is divided into months. We try to guess what we're going to spend this month; hopefully we'll get that. If I have any left over, we try to carry it over to the next month or if it's not enough we try to get more. I don't know if that's the answer you were wanting for the answer for that, as far as allocation goes.

RESEARCHER: That's fine. I just wanted to get an idea of how your company sees the funding issue. As I said earlier, the USAF sees the requirement issue and funding

issue as two different things. Because of that, there is a disconnect. What I'm looking for is if your company has the same difficulty as we have.

FACILITY FOREMAN: Well, I would say that for one thing, the USAF… Your working… You and congress have to do where with us it's the tenant. What the tenant wants, the tenant gets. We really try to go out of our way to please the tenants. If they're happy, if things are going well, their business is doing well, we might get a little bit more. If things are tight or slow, we may have to crank up the belt a few times. And then pray that we don't have anything major go out.

RESEARCHER: Does your company take into account the re-capitalization rate (i.e., length of time required to replace existing facilities at the current rate of investment) of your plant infrastructure when deciding an appropriate allocation rate?

FACILITY MANAGER: That's probably an accountant issue.

RESEARCHER: What I'm thinking here is that Re-capitalization is when you have an old structure and you go in and refurbish it and make it like new again or tear it down and build it new again. That's typically how we look at it in the USAF. We look at it that way. We're either going to replace it outright or go in and reinvest in that facility and make it like new. You probably don't tear down this building every 40-years or so (laughter)

FACILITY MANAGER: Not as far as I know. I don't know what the life expectancy of some of the equipment is but I think were on the edge of some of it since we're 25 years old. A lot of it, we're getting to that point, but it hasn't come to the point where we're going to tear the building down. It's more or less there's a lot of parts such

as cooling tower parts on the roof, there at their life expectancy now, but that's more of a repair or replace rather than total tear down.

RESEARCHER: Does your company or Mead look at this in the long term? You know that the life expectancy of a chiller unit is going to be 15-25 years. Does anybody plan ahead of time that, yeah, it's going to die here soon, we need to start allocating for it now?

FACILITY MANAGER: Yeah, we have three-, five-, and ten-year plans. We try to make projections on stuff like that that is going to need replaced. It may be more efficient to go ahead and do that [now]. So, we have a five-ten year plan for stuff that will need to be replaced in that period of time so they can put out the capital and budget accordingly.

FACILITY FOREMAN: As a matter of fact, we're in the middle of a chiller study right now. We've got recording devices all over our cooling equipment and were doing a study so we can get accurate numbers and prices for chiller replacement. So, in the small term with equipment, yes we do that. In the larger term, that's way out of our league.

RESEARCHER: How do your customers (i.e., senior management, internal employees, and non-employee visitors) feel about the level of quality to which you maintain your facilities?

RESEARCHER: Have any comments been made concerning the acceptableness of the environment you maintain?

FACILITY MANAGER: Well, once a year, we go through, and neutral party comes through and sends out a questionnaire to all of the tenants, which goes back to our

office. They read it and give us feedback. I usually get a copy, maybe three or four months after it's taken. It's usually at the end of the year. They give us grades or rates. They go from 100 to 0. Most of the tenants are pretty happy. There are always a few things they are unhappy with. We rarely get below an 80%. I don't remember exactly what it was last year.

There are different categories. One of the questions is what they would [the tenant] like to see and a lot of the responses have nothing to do with us. For instance, someone wanted ice cream in the vending machine, stuff like that. It has very little to do with us but we get all kinds of comments.

Some of them are compliments. Some are complaints. We try to take it accordingly. That goes out to regional. It's one of the few times we'll get a call from Chicago. They'll see us maybe twice a year. Once on our audit. Maybe one other time when they come in to visit.

FACILITY FOREMAN: We've been the building tour-ers around here. They will bring in a prospective client and we'll give them a tour of how we do things. If they're shopping for new tenants, we'll see them more often. But, obviously not right now since we're all booked up.

RESEARCHER: Can you explain to me any formal or informal methods for customer feedback that you have in place?

FACILITY MANAGER: The survey is really the only formal method we have. But we get plenty of e-mail. Usually not too many compliments, mostly complaints. They say that for every 10 complaints, you may get one compliment. That's probably how it runs [for us] too. You do a good job, and you don't hear anything about it. Ninety-

nine times out of a hundred, things go fine, but that one time that it goes bad is when you hear about it. But as far as a formal thing, we rely on the survey. The other thing is that we rely on phone calls and e-mails.

RESEARCHER: What impact does the perception of the facility condition by the employees working in that facility have on your allocation rate?

FACILITY MANAGER: I don't think it has a whole lot. I think someone else sets it up. Unless there are huge complaints.

I don't know if this had anything to do with it but we just got new lobby furniture, a little face lift down there. I think it was because we were getting a lot of complaints about the lobby looking bad. This is supposed to be Mead Headquarters; it should look a little bet better than that. And I don't know if that had that much to do with it, I mean it was on a three-to-five year [schedule] to change out the furniture anyway. It's kind of like, that sped things along a little bit. I don't think it has a whole lot to actually do with it, what they think of the facility. The money's allocated differently than what people's perception of their workspace is.

RESEARCHER: Any further comments?

FACILITY MANAGER: I think we touched on this earlier. Our biggest thing is our pride in this facility. He's been here 14 years, I've been here 20. We act like this is our home; we treat it like our home. We're not like a contractor who comes in, knocks a job out, and then leaves. We're here all the time; we have to live with it. We do the job right the first time. And I think that shows. I'd much rather have the guys take their time, do a good job, when the job is done we don't have to worry about it anymore. It's not like a lot of residential work where people come in, knock it out and get out in a week.

Leaving it for some one else's problem to deal with. We know that we're probably going to be here for anther 5 or 10 years so we're going to be living with this problem. So, we want to fix it right the first time and then won't have to worry about it anymore. That's probably the biggest thing I'd like to impress on the guy's on the staff. Also, don't do anything that is dangerous or don't feel comfortable with, safety wise. We are a very safety conscious group, we have a lot of safety programs, training, and procedures we go by. We have lock-out/tag-out procedures we follow. We have MSDS sheets. I do not want someone to get hurt if they're uncomfortable working on voltage. We usually have two people working together. It's safety first. As far as lifting, & stuff like that, we want to hoist it correctly. We don't want anyone going out with a back injury. And our safety record has been very good.

FACILITY FOREMAN: We've never had a serious accident.

FACILITY MANAGER: I think that speaks very highly of the crew and our program. That's probably the biggest thing we take pride in. We take pride in this building. It's one of the nicest class "A" office spaces in downtown Dayton. We've got a 100% occupancy rate and were one of the few offices buildings in Dayton that can say that.

FACILITY FOREMAN: If we've got an empty space, it's being remodeled for someone.

FACILITY MANAGER: If we had six more floors, we could rent them right out right now. We must be doing something right. The tenants come here, they like it, and they stay. If you go to any other office building here in downtown [Dayton], they have a lot of vacancies, some of them as high as 50%. That's one thing that, when it's budget

time, or time to renew the contract, it's one of the big things we point to. We've got the building full, the tenants are staying, and everyone is reasonably happy.

FRANCES: I also think it helps to have a crew with longevity. Tim has been here 20 years, I've been here 14 years, another guy has 20+ YEARS, and another has 13 years. So, you get know the tenants. A lot of times, I'll be walking through the building, and somebody will come up to me and say "I've got this problem with …can you guy's help us out?" Sure. We all have two-way radios. If I need somebody, I can get on the radio and call and say "Hey, can you do this for me", "yeah, no problem." So, a lot of times before it would get to the point where it would be a horrible complaint or someone is even a little unhappy, we can handle it then and there. The number one rule is to keep the tenant happy. We will go out of our way to keep them happy and not interfere with their day. If we have to work overtime, we'll do it. If there's something where we need to go in and do something with an area and a tenant is in there and say's they are really busy and can't be out of there, we won't think twice about bringing someone in on the weekend to not interfere with their work schedule. Keep them happy and your job. That's the important stuff.

FACILITY MANAGER: Right now were about 50% Mead, 50% tenant. Like I said, we could have about six more floors and easily rent them out. We've got several tenants that would like to have more space but we just don't have the space to give them.

NCR Corporation

Interview Date: 4 April 2001

Location: Facility maintenance office, NCR Corporate Headquarters, Dayton, Ohio

The following is a transcript of an interview with Mike Freeman, Director of Property Services, Dayton Campus, NCR; Gail Howard, VP Facility Services, Jones Lang LaSalle (NCR's prime contractor for facility services.) and Al Munoz, Facilities Financial Analyst, Dayton Campus, NCR

RESEARCHER: Can you describe the company? Size of the plant and so forth? Also, what is the company's perspective of facilities?

Gale Howard**:** I can probably address the overall. Dayton campus is about two million square feet. In fact, it's still I the declining phases. At one time there were about 21,000 people working here in Dayton and about 33 buildings. We're down to about 12 buildings in a campus setting and about two million square feet and about 3500 NCR employees. Basically, it's all professional office. All of the manufacturing has left town and is now done elsewhere. So, basically, this is the executive offices and support offices and professionals.

RESEARCHER: Is there a particular image that NCR tries to project with the facilities that you maintain?

FACILITY MANAGER: (walks into room) I got the organizational charts that you asked for.

CONTRACT SUPERVISOR: Right on cue.

RESEARCHER: Let me back up. (Repeats the first question)

FACILITY MANAGER: there are a couple of things that you need to understand about what NCR is faced with today. We're in a highly competitive market situation and are primarily looking at our facilities to provide a productive and creative environment for our employees. From that perspective, our company looks to us to provide a productive and creative environment for the employees and obviously meets all of the regulatory and safety requirements and so forth.

Right now, the companies, philosophy is basically that we're looking at how many facilities do we need, can we turn to alternative officing as a possible mode of operation that might be more effective from a cost standpoint. And, to a certain extent, the employee satisfaction standpoint. A lot of our new college hires are very interested in the more flexible, less traditional office environment.

So we're trying to address recruitment and retention of good employees by providing facilities that lend them selves to creativity and productivity. On the other hand, we want to investigate other methods that might be more suited to our other operations, primarily sales and service type functions that don't necessarily need to be housed in offices or buildings.

RESEARCHER: When you say "alternative", what exactly do you mean?

FACILITY MANAGER: Working at home, virtual-officeing. Coming in only to use facilities for meetings and that sort of thing. In the case of our sales organizations throughout the country, we've essentially eliminated most of them and sent those people home to work. They have a place they can come to meet on occasion. But we no longer

have sales offices throughout the country like we once did. So the traditional office is disappearing.

However, here in Dayton, the bulk of what's here are more support, development, infrastructure related type functions, accounting, things of those nature that need to be housed in traditional office environment. We're looking at alternative officeing for some of our folks here to reduce the square footage of space that we have. Primarily, we're looking at people who travel. We're a global company, so we have some groups who are constantly on the road; they're only here one or two days a week. They could work at home, again, in a virtual-office environment and travel. That kind of (officeing), I think, is where we're going with our thinking right now.

We have historically here, the presence we have in Dayton, and we have a headquarters building, which is 450,000 square feet, that was built in the 70s, which is in pretty decent shape. The rest of our facilities are older factory buildings, which date back to the 40s and 50s. We use them now; but, with moving people home or into alternative officing environment and making better use of the space we have, we're hoping to slowly draw ourselves away from those old structures because they just don't lend themselves to long-term, what we want to project as an image of our corporation today. We're no longer in the manufacturing business; we're in "solutions" and high-level computer business. We don't want to be in or perceived as a factory operation anymore. At some point we hope to evolve out of those buildings totally.

So that's kind of the philosophy they've asked us to do. We're in the process now of restructuring our campus to better utilize space by making the office smaller than they are today, in trying to create a little…. That gives us a cost savings, obviously, but it also

allows us to get out of some of these old buildings. We're kind of headed into that mode. Anything we build in the future, as we move out of those old buildings, would be directed at projecting a different kind of image for the company, something that's more in line with the competitors that we deal with; which are mostly California based or Texas based. Most of the companies that we're competing against are new-start companies that have been created in the last twenty years who have built facilities more in tune what we're aiming for. More alternative officing and what you do have are more modern, more open. Different from the traditional environment that we have here. That's kind of where we're at.

Is that what you're looking for?

RESEARCHER: "What I'm looking for" isn't quite the right thing to say. What I'm trying to find out is what the climate is that you're operating under because the "big boss" in the front office is ultimately dictating the way you will be going.

FACILITY MANAGER: It's a constant squeeze between "do it as economically as you can and reduce you're costs" verses "also we want to make our employees satisfied, creative and productive; we want to retain and recruit the best that's out there on the market." Sometimes, that's a conflict that … well, not sometimes. It's a conflict that we live with all the time. It's constantly walking that tight-rope of how we can do that in a cost effective manner to meet the financial objectives while at the same time meeting the human resources side with the recruiting and retention, creativity, and making sure we have up-to-date facilities. So, it's always a tightrope. And I think that anyone who deals with property management deals with the same challenge.

I told you before on the phone that we essentially decided as a company that we don't want to be in the property management business. Most companies are concentrating on their core business and out-sourcing those businesses or parts of their business that really aren't part of their core business. Five years ago, we had 350 people on staff reporting into my organization, doing the property management functions. And that's kind of like a stretch of function; it's not just the traditional property management like the maintenance, custodial and that type of activity. But it's also the office planning, the engineering. We go into services, we do reprographics, photocopying, records retention, food service, security, all of those were in this group. We have successfully outsourced everything except thirty-five people. Thirty people in security and five people, including myself, which now manage the outsourced companies who are performing for us.

Gale (Howard – ed) represents Jones Lang LaSalle who is doing more what is a traditional property management or facility management function**:** The engineering, the maintenance, the cleaning, those types of functions.

Then, we've outsourced to the Xerox Corporation for all of our business services. Xerox Business Services handles photocopy, records retention, shipping and receiving, photography.

Sodexho Marriott Services is the third partner and they have all of the food service and vending. They also run my guest homes. We have two guesthouses that we manage**:** Meringue Farm and Hawthorn Hill. They're both historic sites. We use them for executive housing and Sodexho Marriott manages that function for me, too. They provide us with the lodging aspect of it and also the chef and high-level cooking that goes along with a facility like that. Ones in Kettering, one's in Oakwood.

Those are the three primary strategic partners. We kept in-house all of our asset management, all of our accounting functions related to that. Obviously, we no longer pay bills directly to sub-contractors any more – that goes through Jones Lang LaSalle or one of our other partners. So, we've eliminated a lot of the accounting function that we had before. We still pay our own utilities direct. We'll probably be outsourcing that shortly. There are a lot of companies that manage that and provide you with all the management reports you need to properly manage utilities. Obviously, today that's very critical. Not that it hasn't always been, but today it's more critical with the high cost of utilities. And we're looking at outsourcing some of that.

Security is still in-house. Environmental and Safety – regulatory compliance – is still in house. I have one person who manages that. She has a degree in environmental engineering. We've kept that part of it in house and she interfaces with Gale and Xerox and Marriott, to see that they are fully compliant and that they are training their people properly on hazardous materials or what ever it might be. She ensures that we are totally compliant with all the new regulations that come out on ergonomics …

FACILITY ACCOUNTANT: That includes Fire Safety, too.

FACILITY MANAGER: Fire Safety, that comes under that.

So that's kind of the strategy we adopted five years ago. We've been successful in outsourcing all of it over the last five years. The last piece went out last August, that's when you (JLS) picked up the last building.

We have a campus of about one-and-one-half square feet.

CONTRACT SUPERVISOR: I've been saying "two" until we lose USGN and take all that out.

FACILITY MANAGER: Yeah, I guess that's true. It's two-million now, but we have two buildings that are coming out of service this year**:** one in June and one in August. It'll be down to about a million and a half once we get rid of those two. Last year we got out of a large training facility south of town. So, we have been bringing things in and compacting. Two things have happened**:** We've streamlined our company to focus on our core businesses as we've outsourced or eliminated some of the things that we were doing in the past, we've been able to bring functions in from outside, into Dayton. So We've been successful in doing that and we're going to shut down two more.

So that's the strategy that we've had for the last five years. Going forward, I think we would be looking at how we can get out of some more of these old buildings and perhaps, if the climate's right, long-term what should we do with new buildings and how we should structure the type of operation we want in the future. That's still on the drawing boards. We're struggling.

RESEARCHER: Do you have any documentation to illustrate how your company is organized that I may take with me?

FACILITY MANAGER: Yes. Here is a document that shows how we fit into the F&A end of the business, which is right here.

(Long discussion of who works for who and how many levels of management)

RESEARCHER: Can you explain to me how your organization determines the maintenance requirements for your facilities?

FACILITY MANAGER: That's a broad question. There are two or three different roads we could go down. The first would be our normal, on-going, contracted services. They are all identified in the outsourcing document. We went out and identified

everything that we were doing, to every level that we needed to. We defined what the requirement was and what our expectation was. It was a pretty lengthy document that eventually Jones Lang LaSalle was the winning competitor; so all of what we would call our normal, day-to-day, maintenance activities are defined in that document. And that includes everything from cleaning to maintaining the HVAC equipment, to all systems, plumbing, electrical, whatever.

Now, having said that, there is another piece to it that is all of the assets that we have in those support organizations such as chillers, air handlers, pumps, elevators, roofs, and everything else that we need to maintain.

So, there's really two different levels, at least that's the way I've always looked at it. You have all the service that needs to be done but then there's a whole level of process that says you buy a chiller that's rated to last so long and you have to track that life, look at the repair records and how often you repaired it, how much money you're putting into it and there becomes a point in time when you'll make a decision to replace it.

I think that's the function that you're trying to get to: how do we do that and how do we make those decisions. That primarily has been given to our outsource partner, in their day-to-day activities. Once a year, we get together and prepare a capital budget for any replacements that we think are necessary. That's based on both the life of the asset, the repair record, the criticality of the part such as if it supports a computer room that's top critical. Actually, we have to weight those heavier than the others. That gets into prioritization of what needs to be done in the next year. We then mutually agree what then needs to be done.

That starts the process and we ask for the money at that point.

RESEARCHER: That's getting into allocation (laughs).

FACILITY MANAGER: Yeah, that's getting into allocation. But that starts the process. Gale, do you have anything you want to add?

CONTRACT SUPERVISOR: In fact, I thought I'd put it in writing so I could hand it to you afterwards. I put down exactly the same thing. We started off with a scope of work from NCR that says, "We want you to maintain our equipment, our facilities", a scope of work so to speak, that lists operational process, primers, and expectations. So then we took those and broke them down into preventative maintenance, predictive maintenance, and repairs. Basically, our preventative maintenance is scheduled maintenance per manufacturers specs, standards, and best practices. Predictive maintenance; we don't do a lot here but we do some vibration analysis, infra-red scanning, and eddy-current testing on our big chillers and equipment. Then there's day-to-day repair. Basically, that's a work-order system that been put into place to handle minor repairs and stuff. I kind of alluded to larger expense items are planned and CAR processed. I've kind of come full circle.

FACILITY MANAGER: Obviously, we have to address any emergency breakdowns that occur that may not be planned in the year and we have to get funding when that occurs. So, it can happen in a planned fashion or in an emergency repair mode where we end up making the decision to replace rather than repair. We make those decisions based on the projected remaining life, how much you have to put in it, is it really worth it or is it time to bite the bullet and replace it. Those are individual decisions that we have to make as we go along but we try to avoid that by planning the replacement of the asset in a logical fashion, depending on the availability of funding.

CONTRACT SUPERVISOR: Everything comes back to availability of funding.

FACILITY MANAGER: Yeah, it sure does.

RESEARCHER: This next question goes to the thought process behind why you're doing it that way. Can you explain to me what goals your companies decision makers had in mind when setting up this method of determining the maintenance requirements?

FACILITY MANAGER: There's several. One is tenant satisfaction. How we maintain our equipment and the services we provide are ultimately judged by the tenants of the building, whether we're meeting their requirements or not. In addition to that, I think we're charged with doing it in the most economic fashion available. So, you have the financial aspect of it as well. And, third, we want to protect and maintain the assets so that we get the full, useful life from them.

So, it's a three-phase objective. It's the way the company set it up and the way we go through this process is geared to meet those three primary areas. We, in fact, judge Jones Lang LaSalle both on an annual survey of our tenants, they (tenants) rate all of our services and we follow up. And then, also, how they came in on the budget that we provided for them. We've actually worked out a nice incentive program where if they meet or exceed those then that obviously effects the fee they get, so, it's kind of a nice arrangement that allows us to control it where you don't get in a situation where you spend less money and focus only on cost at the expense of our tenant satisfaction. We can't… You know, we have to balance that. It's that balance that you need to do constantly.

We've emphasized both so you don't get into a situation where we … You can't go the other way either. Sometimes management will ask you to satisfy everybody to the fullest extent about nobody likes the price tag that comes with that. It's that middle of the road that has to be met. I think the way we're structured; we address that pretty effectively today.

I think that anybody that's in this business has to do the same. I'm sure that the folks who run your buildings out there at WP are in the same boat. You're looking to satisfy your tenants and … It's a little less, you don't have as much of a choice in the military. I mean, you're there; you're stationed there for a definite period of time where our tenants can say "Well, I just don't like this place, I'm going to leave and go work for a different company."

It's funny, the reasons why people leave companies. It doesn't fall real high, but it is a consideration. Work environment is a consideration. Pay is usually one and how you're treated and how you're rewarded and your growth potential kind of rank above it but it's right up there. It's an item that people consider. "I come into a high-tech company and you stick me in an old factory, in a cubicle someplace. It's not very warm in the winter and not very cool in the summer. I'm not going to live with it. I don't need to." That's what we fight. We have to ensure that we maintain our levels to what our competition offers in the same area.

RESEARCHER: Excellent point.

What other methods has your company tried prior to implementing this method of determining your maintenance requirements?

FACILITY MANAGER: If you go back in our history, probably the worst situation that we ever had was when I first got in the business in the ‘80s. We had our divisions running their own buildings. Each business unit was responsible for their own buildings that they were in. So, what you had was a disjointed purchasing function, a disjointed objective setting, you had varying levels of tenant satisfaction. It was just very disjointed. We didn’t have any control, it was difficult to control regulatory and safety requirements in that kind of environment. Since 1980, we have… In fact, from ’80 to ’90, we worked towards centralizing all of it into a central campus function here. We took all of the buildings away from the business units and put them under the control of one property management organization. That was probably the transition that was most effective in improving not only the level of service but also impr9oving the amount of money we’re spending. Significant savings were incurred through that consolidation. Primarily, when you’ve got the same engineers looking at the same HVAC systems and looking at what you needed to do, we got a lot more cost savings.

Another thing is that a lot of buildings were let go. Assets weren’t being replaced in a timely fashion. Since everything was based on that business units P&L, they were less likely to replace and spend money effectively, in a planned method. They were spending the money only when it broke down or when they got into a critical situation.

We eliminated all of that by bringing it into a central, focused group. Then, we took it a step further. When we out sourced it to the professional organizations that can concentrate on that type of business, we gained even more efficiency. Really, we’ve gone through two major transformations in this company since 1980. One is the major step of consolidating it and then outsourcing it. There are two distinct efforts I think, that

continually improved and got us focused on those goals that the company wants us to deliver.

FACILITY MANAGER: (to Gale Howard) Is that the way you see it?

CONTRACT SUPERVISOR: I have "standardized service deliverables" which is about the same. (Laughing) We really haven't talked this over.

RESEARCHER: Can you explain to me how your company differentiates between restoration and sustainment?

FACILITY MANAGER: (To Gale Howard) I think that's really answered in your analysis of how we broke out the scope of work. (To Major Sharp) It's very distinctly broken out in our scope of work.

CONTRACT SUPERVISOR: It's sounds almost like a book answer but we define maintenance as "the periodic performance of regularly scheduled tasks needed to optimally maintain and extend the life of the equipment."

FACILITY MANAGER: That's sustainment. That's what you call sustainment.

CONTRACT SUPERVISOR: That's maintenance.

Basically, repairs are specific tasks needed to return a specific piece of equipment back to service or normal operation.

RESEARCHER: Is there any emphasis placed on one or the other?

CONTRACT SUPERVISOR: Quite frankly, we are still… In fact, we just did another facility survey where we went back and checked what we were looking at and unfortunately, we're still at about 30% maintenance to repair work order log. We want to get that percentage up of course. You want the bulk of it to be in the maintenance field and lower your repair costs. We're striving for 60/40.

FACILITY MANAGER: The emphasis for us is to get into the sustainment rather than reactionary mode. And that's where we felt the outsourcing to a company like JLL or any of the other major property management companies would be able to improve that for us. Trying to do that internally was more difficult than having people who specialize in it to get that shifted over.

CONTRACT SUPERVISOR: We were totally reactive, now we're about 21/79 and we're aiming for 60/40.

RESEARCHER: Do you have a particular strategy to get you to that point?

CONTRACT SUPERVISOR: Like I said, the big thing is catching up on logging and measuring. In the scope of work, they not only gave us a scope of work that we needed to do but they also gave us measurements. Once again, you know the old saying "you can't management it if you can't measure it", so that's what we do. We manage and measure. We're out there measuring; we're doing daily logs, tracking, and trend history. We're looking at those types of things and combining that with our predictive, preventative maintenance programs. We're hoping not to see these repair costs. They should go down drastically.

RESEARCHER: What level of in-house maintenance capability does your organization have and what role do they play?

CONTRACT SUPERVISOR: I answered that one real short. I said that we have full service technicians that provide both maintenance and repair. We have the full gamut, though. Basically, we have low-end techs that do the filter changes, bulb changes, basically the day-to-day low-end work. Then we also have several full service techs set up in vehicles; techs that are knowledgeable to the point where they can take a chiller

apart, fix it, and put it back together. We do supplement our in-house technicians with third party contractors when needed. But that's about an 80/20 or 85/15 split being in-house vs. contactor.

RESEARCHER: Do you have any methods that you use for predicting future failures, such as special monitors and so forth?

CONTRACT SUPERVISOR: We call that predictive maintenance. We do vibration analysis on our big air handlers and motors. We do eddy-current testing on our big chillers. And we do infrared testing on our electrical and roofs.

RESEARCHER: Do you only do eddy-current testing on chillers?

CONTRACT SUPERVISOR: Yeah, that's the only thing we do it on, tube bundles. I've heard of people doing it on boilers and things like that, but basically, it's the chillers.

RESEARCHER: How does your organization determine the amount of funds needed for the requirements that have been identified?

FACILITY MANAGER: Two aspects. First, have an annual expense budget that is to support the ongoing maintenance efforts that Gale is delivering. Then we have a pliant capital budget that we use to fund replacements or up-grades. The company expects us to continue to find alternative means of providing these services in a more economical fashion. I guess that's a given. Each year, we're asked to show improvement in our operational budget. We've charged that responsibility to JLL to provide us with recommendations on how we can do that. And that takes a lot of forms**:** Better ways for them to do their jobs, some of the things we talked about before where we do it in house or decide to sub-contract it as needed when it might save money. They can also generate

savings by coming up with better ways of doing the job. And they can also, by applying new technology, recommend capital investments that might return a savings to us on a payback basis. That's how we do the funding for both our expense budget and the capital is driven by what should be replaced or upgraded. Not only do we look at if it's old or falling apart but we also look at how new technology may give us savings by replacing it, which gives us a return. Then we look at periods of return. Normally, we look at 2-years as a very acceptable return, but then in these things sometimes even 5-years is seen as reasonable when we're looking at long term equipment that will be used for 30-years or so.

CONTRACT SUPERVISOR: The other part is that we go from last years budget to this years budget so there's a lot of history involved.

FACILITY MANAGER: The guidelines are "reduce it". (laughs)

CONTRACT SUPERVISOR: Every year, we've reduced it.

FACILITY MANAGER: Yeah, we've been very successful. Again, I think it's a combination of centralization and outsourcing that has allowed us to continually show reductions in cost every year. And I'm not talking huge reductions, but continual reduction. I suppose when we have all new buildings and equipment, we would stop having opportunities for savings. But I think a combination of technological changes in equipment and support services will still give us those opportunities.

Essentially, Gale brings me the annual budget and then works with Al to determine what we need and why. Then we look at it and apply any reductions that are necessary. What can we afford? Really, you do a risk assessment. You said these things are due, but really are they? You rank order them and then start doing risk assessment and making

judgment calls based on what you're parameters are from the financial folks. Same way you guys go through allocation, I'm sure. (laughs)

RESEARCHER: How does your organization actually allocate the funds? Let me define this for you. This is more from a big picture point of view. You have your corporate headquarters and you have the entities that operate directly under them. Do they pass the funds to the entities that then decide what to do with them or are the decisions made at the HQ level and the entities have to act on those decisions?

FACILITY MANAGER: We're only responsible for Dayton. But it works this way through out the world. We develop our budgets and submit them up. They then approve and or adjust accordingly based on funding availability at the corporate level and then we have to live within the parameters that they give us. The decision making on what assets are replaced is pretty much a local decision. That's based on the expertise that we have in-house or what we're buying from our outsourced partner. So, pretty much, we dictate our own budget but again we have to operate within corporate parameters. They don't get specific and tell us "you have to take this out" or that out, usually, they tell us to rank them and you're getting this amount of money. They allow us to make that decision so then the risk is ours and we're going to have to make that risk assessment and say "ok, that's what we're going to do" and here's how we got to it. Then we point out the risk, identify it, and go on from there.

RESEARCHER: But they more or less allocate based on the requirement that you give them**:** "I need this much" therefore, that's what they give you as opposed to "the plant is worth this much so you get this percentage of it".

FACILITY MANAGER: … give us X-amount of dollars. No, it's based on the annual assessment of what you need.

Part of the outsourcing effort was to drive those decisions to a company that specializes in this rather than us trying to make the call. We may not have the expertise that he can draw on from Chicago or Atlanta or various other operations when some things going on. We can get a really good professional assessment (from the outsource partner—ed) of what's going on and what we should do and how we should prioritize. When we get into some of these things, he can draw on a lot of resources to help us make those decisions rather than blindly saying "lets try to make this roof last another year" or what ever.

That's one of the reasons we turned to outsourcing – to help improve those decisions. The actual budget process hasn't changed. They know how much they want to spend, basically allocate on that basis. Sometimes I will get into, on the next level of my management, and say let's look at what San Diego or Atlanta is doing or somewhere else in the world and capital money could be shifted around, again based on a bigger level of prioritization. So, we do have that to fall back on at our level. We're at the end of it but going up, there are bigger chunks that we can look into.

If we comeback with "They're all Priority 'A' this year, we just don't have anything that we're willing to risk," then we have to look for it somewhere else in the global budget. Usually that's the way it works. We don't have to do that very much because usually we can control it within our own sphere of responsibility.

RESEARCHER: Does your company take into account the re-capitalization rate, i.e. the length of time required to replace existing facilities at the current rate of investment in your plant infrastructure when deciding on an allocation rate?

CONTRACT SUPERVISOR: I think they're looking at that more, don't you think so?

FACILITY MANAGER: Yes, I think so. I guess the answer is "yes".

CONTRACT SUPERVISOR: Isn't that one of David Barman's… You know he's got his bogey for return on investment. If you build a business case, even if your trying to fix up a building, he's got to sign the CAR, the Capital Appropriation Request, and he's going to use that.

FACILITY MANAGER: Yeah, I think so. They'll push me. I have an easier time funding for the headquarters (building – ed) than one of the 35-year-old or 40-year-old buildings. They'll often say, "Do we really need to? We're looking at the life of this asset as another three or five years, do we really want to put this kind of money in?" We have to make those kinds of calls where we start looking at what it's going to cost to replace the building and what's the long-term goal. So I guess the answer is "Yes".

RESEARCHER: How do your customers feel about the level of quality that you maintain in your facilities? A customer can be defined as management or anyone who walks through the gate…

FACILITY MANAGER: Our last ratings were close to a four out of five. On a scale of five, we got a four rating. Real close to a four rating from our tenants. That's primarily a measure of our tenant's satisfaction. It was a 3.8 or 3.9, somewhere in that range.

For the kind of buildings that we have, the mix we have, that's really quite good because we have older buildings. Even our headquarters building which we call our flagship building is twenty… the main building is 25-years-old. We're at the half-life. We don't have any really new facilities. You can't expect a lot higher rating than that. I would say that from an outside perception, the headquarters probably measures pretty high as does Sugar Camp. But if I took you into some of our older buildings you'd probably say they were not what you expected for a high level company such

CONTRACT SUPERVISOR: We've classified our buildings…as NCR to still be using. I think that's an honest opinion.

FACILITY MANAGER: We have two buildings that I would classify as high 'B's, then the rest are 'C's, definitely 'C's. That's not so much a reflection of maintenance as of a function of the replacement of the buildings, of funding a major replacement of buildings, which we haven't been able to do. We've talked about it for five years but haven't gotten there yet.

So that's where we are. We're in a situation where we're dealing with older buildings and we're never going to get very high ratings out of those buildings and all you can do is try to maintain them and improve them within the constraints of the budgeting process that we deal with.

We have an annual survey that we give to all of our tenants. In fact, let me get you a copy of that. (leaves the room)

Appendix D: Glossary

BCE: Base Civil Engineer. The BCE is responsible for all facility and infrastructure construction, maintenance, and repair at his or her assigned duty location.

CAT: Condition Analysis Technique. A method used to determine facility maintenance and/or repair requirements. CAT may also be used to determine a level of funding to be allocated to a M&R requirement.

FB: Formula Budget methodology

LCC: Life Cycle Cost methodology

MAJCOM: Abbreviation for "Major Command." Within the USAF, a MAJCOM is a division beneath the Air Staff, such as Air Combat Command. The MAJCOM functions as a division headquarters, responsible for multiple installations within their command.

MILCON: Military Construction. MILCON is the method used by the US Federal Government to oversee facility construction programs estimated to cost in excess of $500,000. Requirements are provided by the branches of the military to the US Congress, which then determines which projects will be funded.

M&R: Maintenance and repair.

PV: Plant Value

MAP: Moraine Assembly Plant. This General Motors plant is located in Moraine, Ohio, and currently assembles mid-size sport utility vehicles for Chevrolet, GMC, and Oldsmobile.

TNAP: Toledo North Assembly Plant. This Daimler-Chrysler plant began construction in 1998 as a replacement for the aging TAP.

TAP: Toledo Assembly Plant. This Daimler-Chrysler plant is the original Jeep production factory. As production is shifted to TNAP, portions of this plant will be demolished.

Appendix E: Facility Maintenance Related Air Force Instructions

Table 11 below describes the instructions and guidance for facility and infrastructure construction, maintenance, and repair for US Air Force real property that were current at the time this research effort was conducted. The column titled "Short Title" is the name by which the guidance is normally referred. The column titled "Title" is the long descriptive title. The column titled "Date" indicates the approval date for that document.

Table 11: USAF Facility Maintenance Instructions and Guidance

Short Title	Title	Date
AFPD32-10	Installations And Facilities	Mar 1995
AFPD32-11	Installations And Facilities	Apr 1998
AFPD32-20	Fire Protection	Jul 1994
AFPD32-60	Housing	Jul 1994
AFPD32-70	Environmental Quality	Jul 1994
AFPD32-90	Real Property Management	Sep 1993
AFI32-1001	Operations Management	Aug 1999
AFI32-1002	Snow And Ice Control	Oct 1999
AFPAM32-1004v1	Working In The Operations Flight Functions And Organization	Sep 1998
AFPAM32-1004v2	Working In The Operations Flight Maintenance Engineering	Sep 1998
AFPAM32-1004v3	Working In The Operations Flight Facility Maintenance	Sep 1998
AFPAM32-1004v4	Working In The Operations Flight Material Acquisition	Sep 1998
AFPAM32-1004v5	Working In The Operations Flight Infrastructure Support	Sep 1998
AFPAM32-1004v6	Working In The Operations Flight Heavy Repair	Sep 1998
AFPAM32-1005	Working In The Engineering Flight	Oct 1999
AFPAM32-1006	Service Contract Guide For Civil Engineers	Nov 1997
AFJMAN32-1008	Installation Design	Mar 1981
AFPAM32-1010	Land Use Planning	Nov 1998
AFI32-1021	Planning And Programming Of Facility Construction Projects	May 1994
AFI32-1022	Planning And Programming Nonappropriated Fund Facility Construction Projects	Jun 1994

AFI32-1023	Design And Construction Standards And Execution Of Facility Construction Projects	Jul 1994
AFI32-1024	Standard Facility Requirements	May 1994
AFJMAN32-1030	Engineering Use Of Geotextiles	Jul 1995
AFI32-1032	Planning And Programming Appropriated Funded Maintenance, Repair, And Construction Projects	Sep 1999
AFJMAN32-1034	Materials Testing	Aug 1987
AFJMAN32-1036	Airfield Pavement Evaluation Concepts	Aug 1988
AFJMAN32-1038	Procedures For Us Army And Us Air Force Airfield Pavement Condition Surveys	Jul 1989
AFI32-1041	Airfield Pavement Evaluation Program	Apr 1994
AFI32-1042	Standards For Marking Airfields	Mar 1994
AFI32-1043	Managing Aircraft Arresting Systems	Nov 1996
AFI32-1044	Visual Air Navigation Systems	Mar 1994
AFJMAN32-1048	Railroad Track Standards	Apr 1991
AFMAN32-1050(I)	Seismic Design Guidelines For Upgrading Existing Buildings	Sep 1988
AFI32-1051	Roof Systems Management	May 1994
AFI32-1052	Facility Asbestos Management	Mar 1994
AFI32-1054	Corrosion Control	Mar 2000
AFJMAN32-1057	High Temperature Water Heating Systems	Dec 1991
Afji32-1058	Masonry Structural Design For Buildings	Oct 1992
AFI32-1061	Providing Utilities To Us Air Force Installations	Dec 1997
AFI32-1062	Electrical Power Plants And Generators	May 1994
AFI32-1063	Electric Power Systems	Mar 1994
AFI32-1064	Electrical Safe Practices	Mar 1994
AFI32-1065	Grounding Systems	Oct 1998
AFI32-1066	Plumbing Systems	May 1994
AFI32-1067	Water Systems	Mar 1994
AFI32-1068	Heating Systems And Unfired Pressure Vessels	Oct 1998
AFI32-1069	Gas Supply And Distribution	Mar 1994
AFJMAN32-1070	Plumbing	Aug 1993
AFMAN32-1076	Design Standards For Visual Air Navigation Facilities	Dec 1997
AFJMAN32-1080	Electrical Power Supply And Distribution	Feb 1995
AFJMAN32-1082	Facilities Engineering - Electrical Exterior Facilities	Nov 1996
AFJMAN32-1083	Electrical Interior Facilities	Nov 1995
AFH32-1084	Facility Requirements	Sep 1996
AFJMAN32-1087	Arctic And Subarctic Construction Foundations For Structures	Oct 1983
AFJPAM32-1088	Bridge Inspection, Maintenance, And Repair	Dec 1994
AFMAN32-1089	Air Force Military Construction And Family Housing Economic Analysis Guide	Aug 1996
AFJMAN32-1090	Noise And Vibration Control	May 1995
AFJMAN32-1091v1	Arctic And Subarctic Construction General Provisions	Sep 1987

AFJMAN32-1091v2	Arctic And Subarctic Construction Site Selection And Development	May 1990
AFMAN32-1093(I)	Energy Monitoring And Control Systems (Emcs)	Jan 1991
AFMAN32-1094	Criteria For Air Force Precision Measurement Equipment Laboratory Design And Construction	Nov 1998
AFPAM32-1097	Sign Standards Pamphlet	Nov 1997
AFPAM32-1098	Base Civil Engineer Self-Help Guide	Apr 1996
AFMAN32-1123(I)	Airfield And Heliport Planning And Design	May 1999
AFH32-1163	Engineering Weather Data	Jul 2000
AFPAM32-1186	Valve-Regulated Lead-Acid Batteries For Stationary Applications	Aug 1999
AFPAM32-1192	Energy Efficient Motors And Adjustable Speed Drives	Aug 2000
AFH32-1290	Cathodic Protection Field Testing	Feb 1999
AFI32-6001	Family Housing Management	Apr 1994
AFI32-6002	Family Housing Planning, Programming, Design, And Construction	May 1997
AFI32-6003	General Officer Quarters	Feb 1998
AFI32-6004	Furnishings Management	May 1994
AFI32-6005	Unaccompanied Housing Management	Jun 1998
AFH32-6009	Housing Handbook	Jun 1996
AFJMAN32-8008v1	General Provisions For Airfield/Heliport Pavement Design	Mar 1994
AFJPAM32-8013v1	Planning And Design Of Roads, Airfields, And Heliports In The Theater Of Operations--Road Design	Aug 1994
AFI32-9001	Acquisition Of Real Property	Jul 1994
AFI32-9002	Use Of Real Property Facilities	Nov 1993
AFI32-9003	Granting Temporary Use Of Air Force Real Property	Aug 1997
AFI32-9004	Disposal Of Real Property	Jul 1994
AFI32-9005	Real Property Accountability And Reporting	Sep 1994
AFI32-9006	Army And Air Force Basic Real Estate Agreements	Feb 1995
AFH32-9007	Managing Air Force Real Property	May 1999
AFI32-9010	Management And Reporting Of Air Force Space And Building Services In GSA And OSD-Controlled Facilities	Jun 2000

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Vita

Major Christopher L. Sharp graduated from West Rusk High School, New London, Texas, in 1982. He was awarded the degree of Bachelor of Science in Electrical Engineering from Texas A&M University in 1987.

Major Sharp was commissioned a Second Lieutenant in the United States Air Force on 4 May 1989 and was subsequently assigned to Moody AFB, Georgia, Kelly AFB, Texas, Incirlik AB, Turkey, and Randolph AFB, Texas. During these varying assignments, he developed both depth and breadth of knowledge of the Civil Engineer career field, working engineering design, project programming, and facility maintenance operations positions at base and Major Command levels.

Major Sharp was selected to pursue an advanced degree at the Graduate School of Engineering and Management, Air Force Institute of Technology, Air University at Wright-Patterson AFB, Ohio, in 1999. His next assignment will be 98th Support Squadron Commander, 98th Range Wing, Nellis AFB, Nevada.