COMPARISON OF TWO MAINTAINABILITY PROGRAMS

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ABSTRACT: Research by the Construction Industry Institute Maintainability Research Team investigated how maintainability is being incorporated into the project delivery process. This paper presents a comparative analysis of two formal maintainability programs drawn from that research. The programs differ in terms of application and project type and size, in addition to the organization leading the implementation (owner-led versus contractor-led). This paper identifies program attributes contributing to effective maintainability programs. These have been grouped into five categories: (1) corporate commitment; (2) program resources; (3) maintainability planning; (4) maintainability implementation; and (5) program updating. Additionally, the comparative analysis provides readers with insights into different applications used to implement maintainability.

INTRODUCTION

Historically, maintenance has been perceived as a ''necessary evil,'' an inevitable cost burden for projects. Yet the maintenance of a facility or subsystem can drastically affect availability, and ultimately, profitability. As costs and competition continue to grow, maintainability has become increasingly important for many owners and design/construction companies. These organizations approach maintenance holistically, meaning maintenance concerns are addressed in project planning, design, scheduling, and construction—in essence throughout a project life cycle. Ideally, these organizations also use established metrics to measure effectiveness of implementation.

For purposes of this paper, maintainability is a design parameter pertaining to the ease of maintenance. A maintainability process is a formal method to incorporate maintenance knowledge and experience into the project delivery process including specific tools to facilitate implementation. A maintainability program is a structured process fortified with corporate resources and support to standardize and increase the predictability of planning and designing for maintainability. Several leading companies have invested considerable time and resources in developing formal maintainability programs to facilitate a timely integration of maintenance concerns into the project delivery process. While these companies have been effective in raising awareness and defining a work process to plan and design for maintainability, opportunities exist for improvement, both at the project and corporate levels.

Whether owner- or contractor-led, maintainability can be effectively implemented in a new or retrofit project. Research conducted by the Construction Industry Institute (CII) Maintainability Research Team reveals the emergence of maintainability programs in varying stages, approaches, and applications (Maintainability Implementation Guide 1999). Based on surveys, interviews, and extensive case studies, the research team identified attributes that positively contribute to effective maintainability programs. These attributes have been used as the evaluation criteria in the comparative analysis of two formal maintainability programs.

While the two maintainability programs differ in terms of the organization leading the implementation (owner versus contractor), both programs use similar means to implement maintainability. The analysis performed below provides insight into the relative effectiveness of the different programs. The data on the programs were obtained through intensive case studies, which included personal interviews with relevant company personnel and examination of each organization's maintainability program manuals. The structure of the analysis is modeled on previous work done on constructability (Constructability Implementation Guide 1993; Russell and Gugel 1993).

ORGANIZATIONAL CHARACTERISTICS

This comparative analysis presents two formal maintainability programs intricately intertwined at the corporate and project levels. The owner-led maintainability program has a corporate component implemented on the project level by the in-house project engineering organization, while the contractor-led program has an owner-defined corporate program implemented at the project level by a third-party contractor. Table 1 presents the salient characteristics for the owner- and contractor-led maintainability programs, while a more detailed explanation of program characteristics follows.

Owner-Led Maintainability Program

Having annual sales of $15 billion in 1998, the owner company manufactures and sells over 50,000 products in 40 merchandise divisions ranging from automotive to healthcare. For this owner, design for maintainability is used to achieve long-term optimal production availability. The owner acknowledges maintainability as an important component of improving profitability and retaining global competitiveness.

The corporation's plant engineering department developed the formal maintainability program that is used for delivering equipment and facility projects over $1.5 million. Briefly, the formal maintainability program defines a work process that contains tools to enhance consistent and effective implementation. Actual project implementation of the maintainability program is the responsibility of the project engineering department, which oversees planning, detailed design, and construction activities. Maintainability input is obtained collectively from various in-house departments, namely engineering, operations and maintenance, safety, and ergonomics. As such, this owner had sufficient in-house capabilities to provide the necessary resources to support a formal maintainability program.

Contractor-Led Maintainability Program

This public owner in the aerospace industry has embraced a new business methodology by contracting with a full-services organization to provide long-term performance through a design/construct/operate/maintain contract. The full-services organization is the third-party contractor responsible for leading, facilitating, and performing maintainability services on site. The contract provides flexibility for the full-services organization to coordinate work among all involved parties,

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TABLE 1. Maintainability Program Characteristics

Characteristic	Maintainability Program	
	Owner-led	Contractor-led
Industry	Manufacturing	Aerospace
Focus area	Manufacturing equipment/facilities	General building equipment/facilities
Project application	Capital projects, new and retrofit	Small capital projects on same owner site
Threshold for usage of maintainability program on a project	More than $1.5 million	Less than $200,000
Responsible party for implementation of maintainability program	Project Engineering Division within the owner organization	Third-party contractor—full-services organization

thereby streamlining the project delivery process. The single point responsibility fosters integrated project delivery, which allows maintainability to be effectively considered during planning, design, and construction phases.

Both the public owner and the third-party full-services organization provide maintenance input and resources for the maintainability program, and this cooperative effort signifies a proactive move by the owner toward a fully integrated project delivery process. The contractor-led maintainability program is facilitated through owner guidelines established in the performance-based contract. The contract term is for 5 years—1 base year plus four 1-year renewals. The firm fixed price of the 5-year contract is $128.2 million. The contract covers small capital projects <$200,000 in construction value with a cap limit of 400 projects per year. The long-term, performance-based contract strongly encourages the full-services organization to design for maintainability, resulting in a project that can be operated and maintained efficiently.

ATTRIBUTES OF MAINTAINABILITY PROGRAM

Table 2 presents the fundamental attributes contributing to effective maintainability in the owner- and contractor-led maintainability programs. The program attributes are categorized into five main groups: (1) corporate commitment; (2) program resources; (3) maintainability planning; (4) maintainability implementation; and (5) program updating. Each program attribute will be presented with a description of key elements and examples. The varying approaches taken by the owner- and contractor-led programs to address each attribute will be compared, allowing readers to compare and contrast similarities and differences in the two maintainability programs.

CORPORATE COMMITMENT

Corporate commitment is essential for success, as it establishes the support and resources needed to develop, implement, and update a maintainability program at the project level. Corporate commitment for maintainability consists of two primary attributes: (1) policy statement; and (2) executive sponsor.

Policy Statement

A policy statement recognizes and emphasizes the importance of maintainability in achieving company goals. Effective policy statements include (1) company commitment to maintainability; (2) definition of maintainability; (3) role of maintainability in business and maintenance goals; and (4) an implementation plan for maintainability. Table 3 includes a sample implementation plan that helps facilitate the integration of maintainability into company culture.

Both owner- and contractor-led programs have policy statements expressing corporate commitment to maintainability. The owner-led program has an informal policy statement endorsed by corporate plant engineering services. Similarly, the contractor-led program has a maintainability policy statement distributed from the public owner to be enforced by the contractor. The policy statement stresses the desired results of designed-in maintenance. Both owners strongly encourage the use of its maintainability work processes, but for corporate-wide compliance, a mandatory policy statement would be necessary.

TABLE 2. Attributes of Maintainability Program

Program attributes	Owner-led	Contractor-led
(a) Corporate Commitment		
Policy statement	Yes	Yes
Executive sponsor	Yes	No
(b) Program Resources		
Designated maintainability personnel		
Corporate level	Yes	No
Project level	Yes	Yes
Written program procedures		
Maintainability design characteristics	Yes	Yes
Metrics or performance measurement criteria	Yes	Yes
Maintainability roles and responsibilities	Yes	Yes
Maintainability activity scheduling	Yes	Yes
Maintainability design approval procedure	No	No
Sample tools	Yes	Yes
Program progress tracking		
Costs/benefits	No	No
Best practices	Yes	No
Information database	No	No
Orientation program	No	No
(c) Maintainability Planning		
Review lessons learned	Yes	Yes
Establish maintainability objectives	Yes	Yes
Maintainability activity and resources planning	Yes	Yes
(d) Maintainability Implementation		
Cross-functional project teams	Yes	Yes
Maintainability meetings	Yes	Yes
Design reviews	Yes	Yes
(e) Program Updating		
Evaluate program	Yes	Yes
Update lessons learned/best practices	No	No
Integration of innovative technology	Yes	Yes

TABLE 3. Sample Implementation Plan for Maintainability

Year	Phase	Goal
1	Informal process	Awareness and appreciation
2	Highly recommended process	Detailed focus
3	Mandatory process	Fully integrated maintainability process

Executive Sponsor

An executive sponsor oversees the formal maintainability program, providing corporate-wide visibility and support. The owner-led program has an executive sponsor in corporate plant

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engineering services with the influence to affect executive decisions made in regard to the maintainability program, such as the assignment of resources. Similarly, the contractor-led program has an owner executive sponsor. To supplement the owner executive sponsor, the third-party contractor leads the maintainability effort through middle management, i.e., engineering and construction supervisors. While the maintainability sponsor in middle management helps champion implementation at the project level, an executive sponsor at the corporate level within the contractor organization may help better allocate corporate resources to support, improve, and expand the maintainability program.

PROGRAM RESOURCES

Program resources provide direct support to the maintainability program. Program resources consist of five attributes: (1) designated maintainability personnel; (2) written program procedures; (3) program progress tracking; (4) information database; and (5) orientation program.

Designated Maintainability Personnel

Designated personnel at corporate and project levels are responsible for directing maintainability implementation. Ideally, a comprehensive maintainability program would have designated corporate- and project-level personnel for support from top to bottom. Corporate-level personnel provide overarching guidance and resources for direct implementation, while project-level personnel execute program activities to achieve improved maintainability. The owner-led program has designated five corporate-level maintainability personnel who provide individual plants with training and support in implementing the maintainability program. In contrast, the contractor-led program has designated project-level maintainability personnel. A middle manager provides guidance in direct implementation of the maintainability program. Additionally, a project-level coordinator is responsible for organizing, scheduling, and executing maintainability activities. Combined, the middle manager and coordinator are directly responsible for maintainability implementation at the project level.

Both programs have designated maintainability personnel suitable for their specific program needs. The owner-led program is implemented on a much larger scale than the contractor-led program; thus, the heightened assistance from corporate-level personnel provides broader company-wide support. In contrast, the contractor-led program implemented for a large owner works more effectively with on-site project-level personnel assigned for direct assistance. Accordingly, corporate-level personnel may not be as necessary or economically justifiable on this smaller scale.

Written Program Procedures

Written program procedures enhance consistent, effective implementation by clearly describing, defining, and structuring a work process. A work process consists of involving the appropriate people, equipped with the necessary resources, to execute project activities enhancing design for maintainability at the precise time. Effective written program procedures outline the following: (1) maintainability design characteristics; (2) metrics or performance measurement criteria related to maintenance; (3) maintainability-related roles and responsibilities; (4) maintainability activity scheduling; (5) maintainability idea approval procedures; and (6) sample tools.

The owner-led program has maintainability program procedures compiled in a well-written program manual. The manual has practical applications that can be used to improve maintainability on projects. The manual describes a work process that directly integrates maintainability activities into the project delivery process. In 10 pages, the manual covers the purpose, justification, features, and work process for maintainability. Additionally, an appendix contains sample tools to assist in project implementation. Specific examples of written program procedures are presented in Table 4.

Similarly, the contractor-led program has both owner- and contractor-defined general program procedures outlining a work process that is simultaneously used for total quality management and maintainability. This work process serves to ensure the coordination of maintainability activities into the project delivery process. The work process consists of two items: (1) work methods; and (2) process coordination methods. Work methods provide details on the necessary supports and procedures for maintainability implementation. This section lists primary roles and responsibilities, in addition to a contactor-defined worksheet that poses questions on the maintenance strategy and maintainability design characteristics. Work methods are arranged with other project activities to form the process coordination methods. Process coordination methods are flowcharts that graphically depict the sequencing of maintainability activities and identify involved project team participants. Process coordination methods combine and integrate information from several sources, including work methods, to address maintainability in the project delivery process.

While both programs have written procedures to provide a strong foundation for maintainability, an opportunity for improvement that neither program benefits from is a maintainability design approval procedure (MDAP). An MDAP is a structured process for determining the inclusion of maintainability design features into a specific project. It defines evaluation criteria, the necessary personnel to involve in approval, and analysis tools to determine economic feasibility. The MDAP can be used to evaluate the application of maintainability ideas and lessons learned to projects. An established MDAP enhances a work process by providing a structured method for evaluating practicality of maintainability features.

Program Progress Tracking

To aid continuous improvement, a maintainability program must document and evaluate effectiveness. The owner-led program collects project feedback through an annual maintainability awards program administered by a corporate-level coordinator. The awards nomination form includes 20 questions

TABLE 4. Examples of Program Procedures

Maintainability design characteristics	Metrics or performance measurement criteria	Maintainability-related roles and responsibilities
Accessibility	Overall equipment effectiveness	Project maintainability champion
Standardization	Mean time to repair	Plant engineering/maintenance
Modularization	Annual maintenance cost	Design engineering
Preferred suppliers	Planned versus unplanned maintenance	Production management
Preventive and predictive maintenance capability	Spare parts inventory	
Visual indicators	Maintenance cost per sales value of production	
	Maintenance cost per unit production	
	Start up costs	

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in which project participants can provide information on the maintainability implementation process, team dynamics, quantitative business objectives, and end results. Projects with successful maintainability implementation are recognized at an annual corporate banquet. The success stories are printed and distributed to plants, thereby establishing visible corporate commitment for maintainability and furthering communication of its successful utilization.

In contrast, the contractor-led program tracks program progress through monthly progress reports compiled by the project-level maintainability coordinator. These reports are provided to the owner with status updates on maintainability activities for projects. The monthly progress reports document (1) number of current projects implementing maintainability activities; (2) new equipment installed; (3) numbers of walkthroughs attended; (4) number of prework meetings attended; and (5) beneficial occupancy turnovers. The reports provide tracking information on projects selected for the maintainability program. However, they do not provide in-depth information on the actual implementation process itself.

Ideally, both quantitative and qualitative measures should be documented in program progress tracking. Additionally, costs and savings stemming from maintainability ideas or implemented lessons learned should also be documented. While both programs track progress to some extent, it was difficult for the authors to locate quantitative program measures. Programs that can establish quantifiable costs and savings are better able to provide economic justification for and benefits of maintainability. Quantitative program costs would include administrative, personnel training, and implementation costs. Quantitative program savings would include overall reduction in maintenance requirements with lower life-cycle costs for projects and increased availability, i.e., less downtime.

Information Database

Information databases are useful tools for capturing and sharing knowledge and experiences to support a maintainability program. Information databases contain lessons learned, best practices, preferred suppliers, life-cycle cost data and models, and other maintenance-related information. Documentation of information is necessary for standards of maintainability best practices to be developed, but to be effective, information databases must be updated and managed to prevent information overload. Information databases that are electronically based provide higher accessibility and efficiency. Both programs could benefit significantly from formalizing the collection of maintainability-related information into an electronic database. Tracking maintainability information would become easier, and this organized information would help determine quantitative benefits and costs.

Orientation Program

An orientation program informs and educates the project team on the maintainability program. An orientation program should include the following: (1) definition of maintainability; (2) barriers, goals, and benefits of maintainability; (3) overview of work process with clear project roles and responsibilities; (4) maintainability concepts; (5) tools and resources available; and (6) project critical success factors.

The owner-led program has a corporate team offering maintainability training and implementation assistance for individual plants on a requested basis. In contrast, the contractor-led program designates the project-level maintainability coordinator responsible for providing informal maintainability orientation to individual project participants. Both programs would benefit from a formal orientation program. The formal orientation program would help to increase awareness and create a common understanding among project team members.

MAINTAINABILITY PLANNING

Planning for maintainability is the deliberate effort to include maintainability into the project delivery process. It consists of three program attributes: (1) review maintainability lessons learned; (2) establish maintainability objectives; and (3) plan activities and resources.

Review Maintainability Lessons Learned

A review of maintainability lessons learned during project planning and before design can prevent costly maintenance errors. Both programs in this study informally review lessons learned, usually at the discretion of the project manager/engineer. A structured formal review of lessons learned for maintainability may require extra project effort up front, but it can potentially save significant time and costs by reducing design and construction rework due to a lack of proper maintainability considerations. A checklist of critical and major project elements can be used to ensure that a thorough review of maintainability lessons learned has been completed.

Establish Maintainability Objectives

Maintainability objectives are governed by the maintenance strategy selected for the project. Maintainability objectives must be clearly defined and must support business goals. While qualitative maintainability objectives are very useful, preference is for quantitative maintainability objectives that can be measured and recorded.

Both programs were able to define quantitative maintainability objectives. The owner-led program uses quantitative objectives such as (1) total spare parts inventory per unit of sales value of production; (2) maintenance cost per unit of sales value of production; (3) maintenance cost per unit of product produced; (4) planned versus unplanned maintenance cost; (5) start-up costs (training, travel, checkout, materials); (6) annual maintenance costs; and (7) overall equipment effectiveness. During project planning and design, maintainability objectives are established by a joint effort of the project engineer and plant/maintenance engineer. The cooperative joint effort increases the likelihood of designed-in maintainability and realistic attainment of maintainability objectives.

In comparison, the contractor-led program identified mean time to repair as a maintainability objective. Other maintainability objectives were not as clearly defined—a common occurrence throughout industry. Maintainability results can be difficult to track or measure because maintenance has initial and long-term impacts occurring over the life cycle of a project. Nonetheless, continuous tracking and measurement of maintainability objectives provides a means to assess true value and performance. The continuous assessment also allows informed decisions to be made for appropriate changes to improve long-term maintainability.

Plan Activities and Resources

Activity and resource planning for maintainability facilitates the implementation process by securing necessary support for timely integration into the project delivery process. Planning for maintainability activities and resources increases the likelihood of effective implementation as it helps to assemble appropriate personnel and expertise during the design process. Both programs have adequate means for planning and coordinating maintainability activities and resources.

The owner-led program uses a checklist to assist planning maintainability activities and required resources. Table 5 presents a condensed example of the checklist. The checklist contains 20 questions addressing maintainability issues in the areas of project teams, project funding, maintainability concepts,

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TABLE 5. Checklist for Planning Maintainability Activities and Resources

Project team	Yes?	No?	Comments
Does the cross-functional project team include operations/ maintenance?			
Is there a designated operations/maintenance personnel for design input and reviews, installation, and start-up?			
Who is responsible for complete operations and maintenance documentation such as manuals?			
Maintainability concepts			
Will the project incorporate the following:			
Preventive maintenance features?			
Predictive maintenance?			
Accessibility for maintenance?			
Safety?			
Ease of alignments and quick changeovers?			

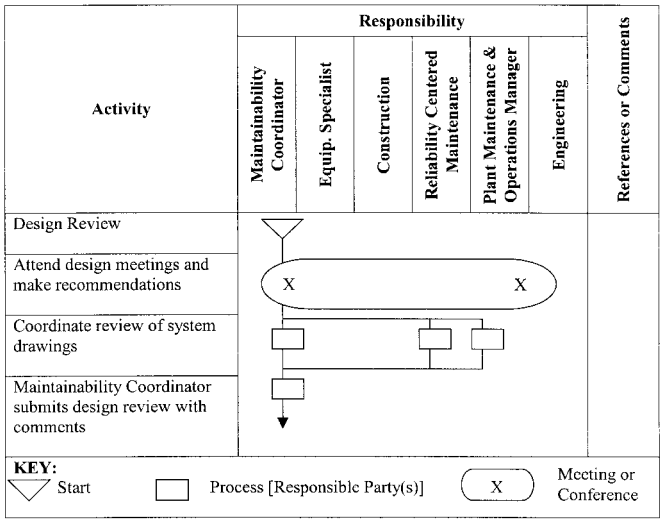

FIG. 1. Flowchart for Activity and Resource Planning

maintenance design considerations, maintenance documentation, and maintenance training. The checklist aids in assigning accountability for the activities. Additionally, individual plants have a contact matrix that identifies subject matter experts (primary and secondary contacts) who can assist project teams in specific areas of maintenance. The combination of the checklist and contact matrix provides users with sufficient tools to plan activities and resources for maintainability implementation.

In comparison, the contractor-led program uses a flowchart to plan and integrate maintainability activities into the project delivery process, shown in Fig. 1. The flowchart helps delineate tasks, assigns lead responsibilities and personnel, and identifies activities such as meetings and conferences. The flowchart is a component of the process coordination methods employed by the contractor-led program to plan and coordinate maintainability activities and resources.

MAINTAINABILITY IMPLEMENTATION

Program resources and planning establish the framework for maintainability implementation. Maintainability implementation consists of three attributes: (1) cross-functional project teams; (2) maintainability meetings; and (3) design reviews.

Cross-Functional Project Teams

Cross-functional project teams that include maintenance personnel are better equipped to address maintainability issues. Not only do maintenance personnel provide valuable insights into maintainability, their involvement helps establish end-user support for the project. Maintenance involvement provides valuable perspectives on long-term operations of the project and assists in optimizing total capital investment. Both programs recognize the importance of incorporating maintenance personnel into the project team.

The owner-led program includes plant engineering/maintenance on the project team. Experienced maintenance personnel typically participate in the design process, write maintenance procedures, and enter information into a computerized maintenance management system. Similarly, the contractor-led program includes maintenance personnel on project teams. The work methods previously discussed call for cross-functional divisions contacted for design input in maintainability, which ensures maintenance participation.

TABLE 6. Maintainability Reviews for Owner-Led Program

Review index	Purpose
Scope	• Review maintainability concepts and identify maintainability resources
Conceptual design	• Review conceptual design to identify opportunities for use of maintainability concepts
Detailed design	• Review detail design to confirm use of maintainability concepts • Identify required tools and training for operations and maintenance
Preinstallation	• Secure equipment, facilities, resources, and personnel available and prepared for installation • Secure training for operations and maintenance
Turnover	• Review entire project to assure it meets project specifications along with maintainability • Assure complete and up-to-date documentation is provided

Maintainability Meetings

Maintainability meetings designate specific venues for the project team to discuss maintainability issues. As shown in Table 6, the owner-led program integrates maintainability issues into five regularly scheduled project meetings in the project delivery process. Each meeting uses a checklist as a guideline for addressing maintainability concerns. Incidentally, the five project meetings correlate with the maintainability reviews. Similarly, the contractor-led program has two scheduled project meetings to discuss maintainability issues. The maintainability coordinator, design engineering, and plant maintenance/operation managers attend these meetings. In addition to the scheduled project meetings, maintenance involvement and input is obtained on an as-needed basis.

Design Reviews

As demonstrated in Table 6, the owner-led program integrates conceptual maintainability reviews into each of the five major project delivery phases: (1) scope; (2) conceptual design; (3) detailed design; (4) preinstallation; and (5) turnover.

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In contrast, the contractor-led program has a typical design process involving three reviews at (1) 30%; (2) 60%; and (3) 90% design complete. Each design review is an opportunity to consider and evaluate maintenance issues. At the very least, almost every project receives a 90% design review for maintainability. Ideally, maintainability programs should include both conceptual and detailed design reviews for a more thorough and complete review.

PROGRAM UPDATING

Continuous improvement requires updating the program to enhance effectiveness and efficiency. Program updating consists of three attributes: (1) evaluate program; (2) update lessons learned; and (3) integrate innovative technology. Both programs could benefit from more extensive updating and recording.

Evaluate Program

The owner-led program evaluates itself through feedback obtained from an annual awards program discussed above. Once a year, the awards program collects information from projects implementing the maintainability program within the past 5 years. With the annual awards program, the owner-led maintainability program is being monitored, evaluated, and updated. In comparison, the contractor-led program uses monthly progress reports to provide an update on project status and applications of the maintainability program. The monthly progress reports assist both the contractor and owner in evaluating the maintainability program. Based on these results, renewal options are available to the contractor in the long-term, performance-based contract.

Update Lessons Learned/Best Practices

Consistently updating lessons learned is important for ensuring that current information is being circulated to project teams. In accordance with research findings in industry, both programs lack a formal method for updating lessons learned. Efforts need to be focused on improving the updating of lessons learned to increase effectiveness of both maintainability programs analyzed.

Integrate Innovative Technology

Integration of innovative technology, advanced maintenance technology, and information management technology enhances proactive maintenance. For example, predictive technologies, such as vibration and thermal analysis, can help prevent failures and reduce downtime. Information management technology, such as a computerized maintenance management system or information database, provides better information accessibility and greater efficiencies. While both programs encourage incorporation of technology, the owner-led program has more resources, funds, and greater long-term motivations to integrate innovative technology into the maintainability program. Still, both programs would reap tangible, quantitative benefits from further technological integration and performance tracking.

SUMMARY

Implementation of maintainability programs is a recent and evolving phenomena. Readers can use the attributes outlined in this comparative analysis to identify strengths and weaknesses in their own maintainability programs, as well as opportunities for improvement. The comparative analysis is valuable to both owners and contractors by providing insights into program attributes and different approaches used to contribute to effective maintainability implementation. As successful maintainability projects emerge and awareness increases, a maintainability program will become a best practice.

The comparative analysis of these two maintainability programs highlighted important attributes that positively impact implementation. Program attributes were grouped into five main areas: (1) corporate commitment; (2) program resources; (3) maintainability planning; (4) maintainability implementation; and (5) program updating. Crucial for long-term success, corporate commitment helps to obtain the necessary program support and resources to facilitate planning and implementation of maintainability. A formalized maintainability program standardizes the work process and improves the predictability of implementation efforts. Collecting feedback and measuring effectiveness is important for continually improving a maintainability program.

Individual strengths arise from the owner- and contractor-led maintainability programs. The owner-led program has high corporate commitment that assigns adequate resources to support and continually improve maintainability implementation. Additionally, the owner-led program has developed written program procedures to provide a well-defined work process that includes implementation tools and quantitative maintainability objectives. Alternatively, the contractor-led program receives focused interest and management from designated project-level personnel who have direct interaction with projects. Additionally, the efficiency and accountability created in delivering maintainable projects from a sole third-party contractor enhances long-term results of design for maintainability. While both owner- and contractor-led programs have strong foundations, both could benefit from an increased focus on documenting and updating maintainability lessons learned and tracking quantitative measures.

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