Implementing Asset Management for the U.S. Army Corps of Engineers Civil Works

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Abstract

The U.S. Army Corps of Engineers (USACE) Civil Works oversees and administers an asset portfolio with more than $250 billion in capital investments and hundreds of operating projects located in all 50 states, as well as several international river basins. Reliable performance of the nation’s investment in infrastructure is essential to the asset portfolio’s ability to deliver safe and dependable service. In response to this need, USACE has developed a conceptual strategic investment framework addressing four main areas (maintenance management, operational condition assessments, risk assessment, and portfolio analytics) to provide improved tools and business processes in order to focus strategic investments on the most mission-critical infrastructure assets/components that: a) are in the worst shape/condition and b) have the highest likelihood of failing and impacting mission delivery, which will c) cause the highest adverse impact to the public and the nation. This application of a cradle to grave lifecycle approach across all Civil Works infrastructure systems will allow USACE to better prioritize limited funding and make improved investment choices at key decision points throughout the complete life cycle of a project. This effort is aligned with ISO 55000 asset management principles and global best practices, adapted to the unique multi-mission and public features of Civil Works infrastructure.

1 Introduction

This effort is intended to align with ISO 55000 principles, and specifically the process outlined in Figure 1[1,2,3]. Due the constraints of this paper it will only be possible to briefly describe the context and provide examples of legacy business area-focused strategic investment compared to the more complex desired future state of informing multi-asset, multi-purpose strategic investment strategies, but that will adequately illustrate the journey that USACE Civil Works has embarked upon with asset management.

Figure 1. ISO 55001 Process Chart and USACE Asset Management Alignment

In the United States system of government the Congress has been entrusted with managing the budget and proposing laws. For the U.S Army Corps of Engineers this has historically meant that Congress passes the legislation authorizing water resources investments, and directing USACE to design, build, and usually operate and maintain those investments. Because of the heightened Congressional interest regarding infrastructure investments in Congressional districts, this typically resulted in a very specific funding direction (also known as ‘earmarks’) became the subject of intense public scrutiny. As a result the earmark process became considerably more public and structured, and some forms of earmarks were banned[4].
At the same time, discretionary spending has been decreasing across the entire U.S. Federal budget, which is also reflected in the significant decline in U.S. infrastructure spending in general[5]. The end result has been decreasing resources to address growing needs, in terms of sustaining or improving water resources infrastructure performance. Also, Congress appropriates the funding for the new and existing Civil Works infrastructure on an annual (or incremental) basis, which can create tremendous inefficiencies that impact the delivery of full national benefits. Finally, because of the long history and relationship with Congress, and the shift from a construction-centric agency to a more operations and maintenance-centric agency in the last 30 years, USACE faces considerable legacy cultural hurdles internally and externally that must be acknowledged and traversed for this effort to be successful. Adopting an enterprise portfolio approach for the entire inventory of these Civil Works investments was identified as a key means to address these issues in order to better preserve the delivery of benefits to the nation.

For more than 230 years, the U.S. Army Corps of Engineers Civil Works (USACE) has been a leader in developing the United States’ water resources and related activities. USACE oversees and administers an asset portfolio with more than $250 billion in capital investments and hundreds of operating projects located in all 50 states, as well as several international river basins. The portfolio continues to deliver daily benefits to almost every U.S. household through the Civil Works missions of flood risk management, navigation (including harbors and waterways), hydropower, recreation, environmental stewardship and restoration, water supply, and emergency response. Examples include:

- A vast network of interconnected coastal and inland navigation waterways that facilitates cost efficient and low-emission transportation of goods and commodities. This system includes 12,000 miles of navigable inland waterways, 926 commercial harbors, and 183 locks.
- An array of 353 hydroelectric power generating units that can provide a generating capacity of 20,500 megawatts, or three percent of the nation’s total electric energy need.
- Some 14,700 miles of federally constructed levees in the U.S. that help manage and reduce flood risk to people, homes, and communities.
- Recreation areas associated with the 708 dams, 56,000 miles of lake and river shoreline and 11.7 million acres of public lands that are managed by the USACE Civil Works. 370 million people visit these areas annually helping to support an estimated 350,000 jobs and generating up to $18 billion annually in consumer spending.

These are served by 7 main business areas of Navigation, Flood Risk Management, Hydropower, Recreation, Environmental Stewardship, Environmental Restoration, and Water Supply. In addition to the contextual complexities outlined above, nearly all of the USACE Civil Works project sites serve multiple missions, and the assets at those sites are also multi-purpose (one dam typically provides benefits to most of the business areas listed).

The challenge of maintaining the benefits provided by these assets is formidable and USACE Civil Works must wisely manage resources to continue to fulfill its various mission requirements under increasingly tight budget constraints.

As USACE moves through the 21st Century, it will continue to advance the Civil Works Program strategic goals: assisting in providing for safe and resilient communities and infrastructure; helping facilitate commercial navigation in an environmentally and economically sustainable fashion; restoring degraded aquatic ecosystems and preventing future environmental losses; and implementing effective, reliable, and adaptive life-cycle performance management of infrastructure.

Reliable performance of the nation’s investment in infrastructure is essential to the asset portfolio’s ability to deliver safe and dependable service. This emphasizes adaptive operation and management of existing USACE projects throughout their life cycle, and reflects the implementation of risk-based asset management in the area of operations and maintenance of USACE infrastructure. To achieve this, in 2009 USACE adapted PAS 55 asset management principles and global best practices to develop asset management strategies, assessment tools and processes, and funding initiatives adapted to the unique multi-mission and public features of Civil Works infrastructure. With the development of ISO 55000 standards, USACE has continued to adapt these principles as applicable to the unique circumstances of its public water resources mission – for instance, adapting the ‘alignment’ or line-of-sight ISO principle through efforts to establish ‘asset visibility’, which includes the investments and performance associated with particular assets. These efforts are helping to prioritize USACE infrastructure investments and lay a strategic foundation to achieve long-term sustainability and reliability in its role as a major steward of the United States’ water resources infrastructure[6].

2 Methodology

The objective of the USACE Civil Works Asset Management (AM) effort is to develop and implement a risk-informed investment strategy for managing the USACE Civil Works infrastructure portfolio that will optimize national benefits to achieve the goals detailed above[7]. Within this objective lie two major thrusts:

a) The development of appropriate procedures to quantify and analyze asset data and relationships; and,

b) The development of disciplined business behavior to build robust processes within which to apply these procedures.

The achievement of this corporate objective will provide common and consistent policies, practices and procedures used to inventory, assess, and determine each asset’s strengths,
weaknesses, and value to its expected mission. This objective will:

- Provide a framework for enterprise-level strategic planning, design, construction, operations, maintenance, recapitalization and disposition decision-making
- Provide quantitative information to support development of defensible budgets right-size the asset inventory by considering a full range of lifecycle benefits, risk/consequences of failure within a system and investment costs
- Identify alternative capital investment strategies and quantify corresponding risks.
- Help USACE Civil Works improve reliability, minimize risk and meet projected infrastructure demands
- Formalize business processes that standardize best practices, promote accountability and predict work requirements
- Help USACE Civil Works make resource decisions based on what is best for the nation
- Enable USACE Civil Works to communicate asset inventory and risk-based assessments to external stakeholders and decision makers
- Formalize Asset Management data requirements as part of a unified lifecycle data management plan to enable the flow of relevant technical information using geospatial engineering technologies from other phases of a project’s life cycle

USACE Civil Works AM is an integrated effort to encompass the full lifecycle of Civil Works assets. The initiative cuts across business, organizational, and functional areas to ensure long-term sustainability of Civil Works missions and programs. The USACE Civil Works AM vision is:

“A persistent catalyst for holistically integrating and enhancing the initiation, sustainment, restoration, modernization and disposition of USACE water resources to continually serve the nation”

To achieve corporate consistency, implementation of asset management within USACE Civil Works requires formalization of business processes and integration across business areas and major programs, and incorporation of asset management data requirements into all phases of a project lifecycle. For this endeavor to be effective, congruent basic principles or tenets must be embedded into all decisions and developed products. The USACE Civil Works AM tenets are:

Mission – In concert with and supportive of USACE official water resource mission, service and related responsibilities

Consistent – Common, repeatable application across USACE Civil Works that does not conflict with other current or planned asset management efforts

Reasonable – Logical, rational and implementable in a sound, sensible manner based on good use of resources

Sustainable – Capable of continued implementation and application based on reasonable resource expectations and/or availability

Defensible – Having sufficient rigor, detail and documentation to withstand internal and external review (i.e., auditable, transparent, repeatable and unbiased)

To achieve this, the USACE AM effort uses a conceptual strategic investment framework to focus across four main development areas: maintenance management, operational condition assessments, risk assessment, and portfolio analytics. These areas link closely together to provide improved tools and business processes to focus strategic investments on the most mission-critical infrastructure assets/components that: a) are in the worst shape/condition and b) have the highest likelihood of failing and impacting mission delivery, which will c) cause the highest adverse impact to the public and the nation. The framework also allows the application of these same approaches to planning for new infrastructure as well as the disposition of infrastructure that’s no longer needed. The evolution of this framework is shown first in Figure 2 using a single-mission example, which relates the assets to their specific mission or purpose, and then to the anticipated Value to the Nation (VTN, or benefits):

![Figure 2. Single Mission Example](image-url)
recognize that the degraded condition or failure of the locks and dams will have different consequences from the vantage point of the Navigation, Recreation, and the Water Supply missions. For example, a low navigation pool may cease barge transportation (i.e. loss of economic benefit) but may have little or no effect on recreation (quality of life) and water supply (environmental benefit).

The asset, mission, and VTN relationship, in combination with the condition and risk relationship, provide the basis of a risk-informed methodology to support lifecycle investment decisions. The keys to understanding the USACE Civil Works asset management approach are identifying:

- What assets are being managed (i.e., an accurate inventory of existing or proposed)
- What are the conditions of the assets (i.e., consistent and comprehensive condition assessments)
- How the assets are cared for (i.e., a well-defined maintenance management program)
- Which assets are critical to mission success (i.e., relationships between assets and VTN)
- What are investment priorities for limited funds given conditions and risks (or consequences) of mission failure (i.e., understanding risks associated with assets degradation or failure and VTN)
- Which lifecycle investment alternatives are best for a given asset (i.e., initiate, sustain, restore, modernize, or divest)

Adapting these considerations to the multi-asset, multi-mission reality of USACE Civil Works results in a much more robust framework typical of most USACE Civil Works projects that conceptually links the basic elements of USACE asset management, as shown in Figure 3:

This framework (known as the Civil Works Strategic Investment Framework, or CW-SIF) has the added advantage of being spatially and temporally agnostic, which allows its application to more complex investment issues related to systematic and geospatial contexts such as a particular interrelated system of projects or watershed, as well as to life cycle planning from conception through disposition. Because of this, the USACE Asset Management effort is a key enabler to and dovetails very well with the major elements of the current USACE Civil Works Strategic Plan, which are focused on a system approach, the use of risk-informed decision making and communication, and a life cycle perspective in order to achieve integrated water resource management.

This application of a cradle to grave lifecycle approach across all Civil Works infrastructure systems will allow USACE to better prioritize limited funding and make improved investment choices at key decision points throughout the complete life cycle of a project. This is being accomplished through the two main thrusts of the overall USACE Asset Management objective, which are being pursued with 3 specific focus areas as follows:

a) The development of appropriate procedures and tools to quantify and analyze asset data and relationships (Focus Areas 1 and 2); and

b) The development of disciplined business behavior to build robust processes within which to apply the use of those procedures and tools (Focus Area 3).

Focus Areas 1 and 2 provide the appropriate emphasis and direction for the development of appropriate tools and analytical capabilities while Focus Area 3 drives the required disciplined business behavior to leverage those tools for effective asset management. In simple terms, the activities in these focus areas allow the development of the CW-SIF concepts into tangible, practical, useful tools and processes – in line with the USACE AM tenets detailed earlier.

Focus Area 1: Focus Area 1 includes the basic building blocks of a risk-informed asset management strategy. In order to move from subjective to more objective inventory and assessment processes, consistent, repeatable, transparent and standardized methods for inventory, condition assessment, risk assessment, cost assessments, and maintenance management must be in place. Focus Area 1 incorporates a strong emphasis on the development of a complete understanding of the existing USACE Civil Works asset inventory, condition, and risk as a baseline for establishing appropriate maintenance management objectives to address the deteriorating performance of USACE Civil Works infrastructure. This focus area is not only business area focused (Navigation, Hydropower, etc.), but also specific project site and O&M budget account focused. Data associated with these efforts will directly tie to and support advancement of the Foundation in Focus Areas 2.

Focus Area 2: The asset management process must consider the interdependencies of the entire asset portfolio and impacts not only at a limited static point in time but also throughout the dynamic range of the assets’ entire lifecycle. This focus area represents the full transition from a business area centric approach to a true portfolio approach which better represents and recognizes each asset’s contribution to the Value to the Nation within a system. This enables knowledge and decisions
to be based on an overall understanding of tradeoffs associated with portfolio risks and benefits. One key initiative in this focus area is identification of new sources of funding to support strategic Recapitalization of USACE Civil Works infrastructure as warranted. The asset management principles and processes developed and implemented will primarily determine the “what, where and when” for the lifecycle investment strategy; the Recapitalization effort will identify legislative and alternative financial initiatives necessary to determine “how” to accomplish infrastructure revitalization.

**Focus Area 3:** Focus Areas 1 and 2 deal with the development and implementation of the conceptual framework to assist risk-informed decision analysis. Focus Area 3 involves establishing activities and processes that will emplace the asset management process throughout USACE Civil Works. It includes: a) emphasis on integration and collaboration of organizational efforts to achieve efficiency and elimination of duplicative activities; b) communication and education of asset management principles and tenets; c) defining metrics and standards to measure performance; and d) assessment and adjustments to ensure sustainability and credibility of the asset management efforts.

Because of the integrated nature of USACE Civil Works Asset Management, the activities and outputs of these focus areas are linked and may even occasionally overlap to varying degrees. The completion of the activities must satisfy the following specific goals:

- Provide consistent and common business process for assessing asset conditions and risks associated with asset failure
- Provide risk-informed business processes that incorporate lifecycle and systems considerations for performing trade-off analyses and for portfolio investment decisions
- Provide communication and collaboration strategies to instill asset management concepts and principles throughout USACE Civil Works

**3 Examples**

The tools and business processes developed as part of this effort have been used to implement strategic maintenance management including improved asset visibility, accurate maintenance requirements, and maintenance planning, execution, and analysis; complete operational condition assessments for over 9,000 major assets and associated components; and the development of risk analyses using that maintenance and condition information. Specific representative examples of outcomes from USACE Asset Management development and implementation are the development of heat maps to optimize dredging of coastal navigation channels using seamless data collection; multi-year capital investment strategies for navigation locks and hydropower plants; and a 3-year glide path to transform the current Operations and Maintenance budget process to using risk information to prioritize approximately $3 billion in annual funding to maximize its effectiveness.

In 2011 USACE recognized that the new budgeting and appropriations climate was diametrically opposed to the continuing escalation in dredging costs. It became clear that a method to help optimize dredging projects in terms of both schedule and cost was necessary.

First, a major effort was undertaken to develop more consistent data collection and processing methods for the over 12,000 miles of navigational channels USACE is responsible for. By 2014 this resulted in a nationally consistent electronic process of hydrographic survey data collection and formatting. With this information and an accurate channel design template, shoaling rates could be predicted (analogous to the probability of failure of a navigation channel) and those predictions combined with the consequence information of shipping impacts contained in a USACE Channel Portfolio Tool (CPT) to develop risk assessments for various predicted channel shoaling conditions over time. The results are plotted on a heat map showing the optimal ‘window’ (in green) in terms of both time and depth to dredge various channels, as shown in Figures 4 and 5:

![Figure 4. Jacksonville Harbor Entrance Channel Dredge Cycle Optimization](image-url)
Figure 5 indicates that the Jacksonville Entrance channel optimally should be dredged every 4 years to the full authorized depth of 45 feet, while Figure 5 shows that the Upper channel could be optimized by dredging it every 4 years to a depth of 32 to 38 feet as opposed to its authorized full depth of 40 feet. Additionally, Figure 6 shows that the shipping volumes at specific channel depths do not vary much over time, indicating that changes in shoaling over 1 to 4 years do not significantly impact navigational shipping.

Figure 6. Shipping Volume, Time vs. Channel Depth

Jacksonville Entrance and Upper channels had historically been funded for dredging to full depth every year, while Figure 5 shows that the Upper channel could be optimized by dredging it every 4 years to a depth of 32 to 38 feet as opposed to its authorized full depth of 40 feet. Additionally, Figure 6 shows that the shipping volumes at specific channel depths do not vary much over time, indicating that changes in shoaling over 1 to 4 years do not significantly impact navigational shipping.

Risk-informed methodology was also used to develop the recent Congressionally mandated 20-year Capital Investment Strategy for Inland Navigation Locks (CIS) as evidenced by the following quote:[8]:

“Risk-informed asset management principles and processes now enable USACE to gain considerable insights into management and investment opportunities and strategies for the navigation portfolio. Determining those projects that have the highest risk requires identifying those mission-critical components that are in the worst shape/condition, have the highest likelihood of failing, and would cause the highest economic impact on shippers and carriers. Each lock and dam project site has hundreds of critical mechanical, electrical, and structural components, and the failure of any one of them could cause an unscheduled unavailability (outage) of one day or longer. In order to understand the overall project “exposure” to the risk potential of each of these critical components, one must understand the concept of Risk Exposure.”

Operational Risk Exposure (ORE) – the total risk exposure at a project site resulting from those mission critical components that are already impacting performance (Conditions “C” through “F”).

Residual Risk Exposure (RRE) – the remaining, or residual risk (per the International Organization for Standardization definition), after a “risk treatment,” which generally means that a repair or replacement has been done. Further, since a repair is currently equated to returning a component to a “B” condition and a replacement is equated to providing a component in an “A” condition, all components currently in those conditions are also considered as contributing to residual risk.”

This was developed from a prototype Operational Risk Assessment (ORA) of performance-impacting inland navigation lock components developed to provide risk-informed investment decision support during the annual budget process. The CIS expanded that ORA concept to analyze all of the navigation lock components at all of the USACE locks, thus providing a system view and a life cycle perspective for the highest-risk needs – the Operational Risk Exposure (ORE). This allowed the characterization of projects as well as specific assets or components by risk to help inform the overall long-term investment decision process, as illustrated in Figure 7:
The CIS is an excellent example of asset management principles in action, using risk-informed decision making and communication to outline a system-based approach to long-term sustainment and improvement of infrastructure.

A very similar example is USACE’s Hydropower Modernization Initiative, also a 20-year plan to prioritize capital improvements to Civil Works hydropower plants that uses risk information as the underlying methodology. This has been used for the past 5 years as part of the annual budget process for hydropower and has resulted in significant performance improvements in the hydropower business area.

Lastly, these successful examples of asset management principles in application have encouraged its use as an organizing principle in the transformation of the USACE Operations and Maintenance budgeting process itself. A three-year glide path has been outlined for the fiscal years 2018 through 2020 that specifies the adoption of system-based, risk-informed, and life cycle focused methods in describing, linking, and prioritizing approximately $3 billion in infrastructure investments to buy down the greatest risk exposure and maximize or improve the effective delivery of national benefits. These methods span from specifying new, more precise nomenclature across the enterprise to the development of a common enterprise value model and decision quality improvement with which to evaluate various investment choices[9,10], and include the application of all the continued USACE Asset Management efforts and focus areas as well. The adoption of this approach, and of USACE Civil Works AM to inform this approach to such as great extent, speaks to the recognition of the advantages gained to date through the implementation of ISO 55000-aligned asset management principles.

4 Conclusions

All of the foregoing may sound interesting in and of itself, but since this effort is intended to align with ISO 55000 principles it has proved useful to actually examine these elements in relation to ISO 55000. Examination of the process chart in Figure 8.a. and 8.b. shows that the major elements of the USACE Asset Management effort do indeed line up with the
Specifically, the Civil Works Strategic Investment Framework (CW-SIF) lines up with ISO 55000 elements 4.1 through 4.3, 5.1, 5.3, and 6.2.1. Formal guidance dated December 2014 from the Director of Civil Works (DCW) establishing the USACE Asset Management effort as the means to develop and implement this risk-informed, system-based, and life cycle view of Civil Works investments aligns with ISO element 5.2. Lastly, the current risk analyses and budget transformation efforts utilizing all the tools and processes developed and being implemented through the 3 focus areas and 4 main development areas of USACE Asset Management align with ISO elements 4.4, 6.1, 6.2.2, 7.1 through 7.6, 8.1 through 8.3, 9.1 through 9.3, and 10.

While this paper has been focused on primarily the technical elements of asset management implementation, it would be remiss if the cultural and organizational elements were not mentioned. Any change can be perceived as a threat to the status quo of an organization and hence is usually inherently resisted, unless the value of the change can be adequately communicated and understood. The specific improvements USACE Civil Works is pursuing consist of technical advances such as better (but not necessarily more) definitions, data, and analysis; process improvements, such as seamlessly linking the four development areas using a system approach and life cycle perspective; and numerous cultural changes, the largest component of which will be a shift from basing decisions on historical perceptions to basing them more on facts along with consistent measures of efficiency and mission performance. Other cultural challenges include the historical ‘silos’ of efforts, and a higher focus on developing new water resources projects rather than on managing the enterprise of both new and existing ones.

In some respects these cultural and organizational challenges dwarf the technical ones, and are often the reason for poor adoption or less-than-full implementation of any asset management effort. This is often the part of implementation most easily overlooked or assumed[11]; for this reason the USACE effort is trying to maintain a significant focus on education, communication, and outreach to complement the development and implementation of the technical pieces. The basic view is that if this approach to asset management does not provide value throughout the organization, and particularly to the local operation of specific water resource infrastructure such as a hydropower plant or navigation lock, then it will not be readily adopted and it will not truly be an enterprise solution. Therefore it has been recognized that winning the hearts and minds of USACE Civil Works operators, managers, and field personnel by providing that value is crucial to the success of this effort.

The development of USACE asset management in relationship to ISO 55000 principles has produced significant benefits and insights, even at its current early stages of maturity. Its accomplishments to date in improving infrastructure life cycle performance with risk-informed decisions have demonstrated the efficacy of an approach aligned with ISO 55000, even for a complex public service agency such as the U.S. Army Corps of Engineers Civil Works. The planned future enhancements and continued maturity are expected to produce additional benefits in terms of internal alignment and efficiencies, improved communication and credibility, and overall improvement in management of the United States’ water resources infrastructure. Even partial implementation of these improvements will allow the development and support of a much better platform from which to debate the pros and cons of various investment strategies to building, sustaining, and improving water resources infrastructure in the United States.

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References


